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SEP 77 J BOWMAN, R DOUGLAS, R GIUNTINI DOT-CG-40672-A
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AN EVALUATION OF PERFORMANCE AND EFFECTIVENESS OF A MAN OVERBOARD DETECTION AND LOCATION SYSTEM.

9 Final rept. Aug 76 – Sep 77,

14 MSR-77-62

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FINAL REPORT

Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
Office of Research and Development
Washington, D.C. 20590

405 950

NOTICE

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3+4X

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CG-D-71-77		

4. Title and Subtitle	5. Report Date
AN EVALUATION OF PERFORMANCE AND EFFECTIVENESS OF A MAN OVERBOARD DETECTION AND LOCATION SYSTEM	September 1977
	6. Performing Organization Code
7. Author(s) J. Bowman, R. Douglas, R. Giuntini, D. Lunn, E. Sager, R. White	8. Performing Organization Report No. MSR 77-62
9. Performing Organization Name and Address Wyle Laboratories P. O. Box 1008 Huntsville, AL 35807	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DOT-CG-40672-A (T.O. 28)
12. Sponsoring Agency Name and Address U. S. Department of Transportation United States Coast Guard Office of Research and Development Washington, DC 20590	13. Type of Report and Period Covered Final Report August 1976 - September 1977 14. Sponsoring Agency Code G-DSA

15. Supplementary Notes

16. Abstract

This project deals with development of a man overboard detection and location system for use on documented vessels. Preliminary research indicated that radio (RF) systems offered more potential than sonar. The concept for use of the RF system involves a small transmitter the size of a metal tape rule to be worn by each crewman while on deck. In the event of a fall overboard, the unit automatically begins transmitting which actuates an alarm and serves as a homing device for rescue.

The major part of this effort was the demonstration of successful reception of an RF signal from a small prototype man overboard type of transmitter located at varying depths in fresh and salt water. Range for fresh water tests was greater than one mile. Range for salt water was considerably less. A program for development of an operational man overboard system for Great Lakes, inland waters/rivers, and deep sea vessels is discussed.

17. Key Words	18. Distribution Statement
Man Overboard System Man Overboard Detection Man Overboard Location	Document is available to the U. S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	78	

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METRIC CONVERSION FACTORS

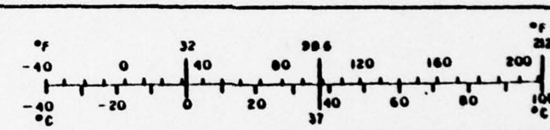
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares ($10,000\ m^2$)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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AN EVALUATION OF PERFORMANCE AND EFFECTIVENESS OF A MAN OVERBOARD DETECTION AND LOCATION SYSTEM

1.0 INTRODUCTION AND SUMMARY

1.1 Background

Previous Coast Guard work has indicated a necessity for a man-overboard detection and location system for merchantmen, particularly on the Great Lakes. Operations Research (Reference 1) performed a feasibility study examining various methods to accomplish this task. The different methods which were reviewed ranged from laser, radio, and sonar to mechanical systems.

Simply stated, the problem is that a crewman who falls overboard may remain undetected by anyone aboard; and even if his fall overboard is detected, he is very difficult to locate in time for rescue.

Results of a study on survival requirements on the Great Lakes (Reference 2) conclude that:

- Man Overboard events constitute a major source of personnel losses
- A substantial need exists for survival system capabilities that will reduce the time delay in activation of rescue actions
- Survival systems capabilities are needed that will provide improved personnel protection from adverse environmental conditions.

The problem addressed by the present work is the detection and location of a man overboard. This problem is two part in nature: detection of the man overboard situation and the location of the man in the water. Ideally the problem could be solved by only one mechanism. Each part of the problem is also broken into two phases depending on when they are required to be in port near docking facilities (or anchored) or underway in open water. Along with a system designed to meet the criteria of detection and location, there must exist a formal executable recovery plan designed to expedite the recovery operation in a minimum elapsed time. This recovery plan (not formally a part of this work) should be defined in consideration of varying locations and performance characteristics of the vessels themselves. A general operational plan is presented in Appendix B.

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A review of available literature and requirements has prompted the consideration of several approaches to the resolution of the man overboard problem. The rescue problem (rescue boat) is being addressed by another Coast Guard project (CG 61,276 A). The approach discussed in the present report was formulated considering the personnel, the environment, and vessel. It does not require a rescue boat, but would certainly be enhanced by such a vehicle.

The work reported herein is expected to be the Phase I of a three phase program aimed at solving the detection and location problem. The three phases are:

Phase I	-	Problem definition, preliminary testing and system selection
Phase II	-	Final system selection, development and evaluation in marine environment
Phase III	-	Final system specification, operational manual(s), components, parts lists, etc., and final report

1.2 Approach

The approach reported includes a literature survey, examination of existing hardware, an analysis of any resulting viable systems for feasibility, the acquisition of prototype or off-the-shelf hardware, the testing and evaluation of this hardware, and an analysis of the results of all the above.

The Coast Guard task order requested that both radio (RF) and sonar type devices be considered. As the work progressed, it was decided that the sonar approach would be considerably more difficult to use in Great Lakes operating vessels due to maintenance and operating problems - especially since the sensor must be exposed and be underwater. Consequently the majority of the work was in the design, fabrication, and testing of a small (metal tape measure size) lightweight RF transmitter.

1.3 Results

The transmitter was designed to be self-contained and to transmit a signal from underwater to an above-water receiver. Details of the transmitter are discussed in the report as are the testing and results.

Concisely, the transmitter worked very well in (under) fresh water; the signal was detectable at ranges up to over a mile while the transmitter was submerged at depths up to 3 ft. Tests in salt water, however, produced the predicted result of very limited range when submerged to any significant depth. The primary problem was that the optimum frequencies for transmitting a signal in salt water were too low for the size of a loop antenna that could be contained within the transmitting unit. The higher frequencies necessary for the small loop antenna severely limited the ability of the RF signal to break the surface of the salt water. Consequently, use of the present transmitter with its small antenna is limited to fresh water use.

The RF transmitter can be easily adaptable to wearing on a belt or in a pocket of a life preserver or other protective clothing. No testing was done on the actual activation switch or the direction finding equipment because previous work has shown that both these areas are entirely feasible.

The report describes several problem areas and possible solutions to these problems for future work in Phase II of the program. The main problem area involved the selection of the lowest possible transmitting frequency while keeping the antenna loop size reasonable (the loop size required increases as the frequency decreases). Other problems include the acquisition of an appropriate water activated switch (or other activation device) to activate the transmitter on impact with the water, and the selection and testing of direction finding equipment, preferably automatic direction finding (ADF).

1.4 Report Organization

The body of this report presents the results of the literature survey (Section 2.1), a problem review (Section 2.2), special considerations (Section 2.3), comparison of some existing equipment (Section 2.4), a description of the selected demonstration device (Section 3.0), and conclusion and recommendations (Section 4.0).

Appendix A is a complete description of the testing and data obtained on the demonstration devices. Appendix B presents one practical conception of a man overboard system (MOS) and its usage.

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2.0 BACKGROUND AND METHODS CONSIDERED

2.1 Literature Survey - Review of Previous Work

To initiate this task, an information search was conducted to determine any previous research relevant to the Man Overboard System (MOS). A request was made to the Redstone Scientific Information Center (RSIC) to perform a "word scan" on this subject.

A RSIC printout of potential sources of information provided no worthwhile information. Several telephone contacts were made with the Department of the Navy and other organizations believed to have some familiarity with closely related applications. Among those organizations contacted were the following:

- Naval Research Laboratory
- Navy Systems Development (Survivability Branch)
- Deep Submergence Systems (Navy)
- Navy Central Instrumentation
- Navy Air Systems
- Office of Research (Navy)
- U. S. Merchant Marine Academy (Research and Development), Kings Point, N.Y.
- Smithsonian Institute
- National Geographic
- Maritime Institute of Technology (Linthicum Hts., Maryland)
- Lincoln Park Zoo (Chicago, Illinois)
- University of Illinois (Urbana, Illinois)
- Masters, Mates, and Pilots (Labor Union)
- Seafarers International Union including the Harry Lundeberg School of Seamanship

The various Navy offices, Merchant Marine Academy, Labor Unions, and Maritime Institute of Technology were contacted because of their involvement with shipboard hardware and systems as well as an expected interest and familiarity with the man overboard problem. From this sampling of the scientific community, it has been concluded that no comprehensive research has been performed on a MOS or similar device. Some individuals within the Department of the Navy were sympathetic with the cause and were helpful by providing other potential information sources and

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people that might provide some enlightment on the problem. National Geographic, Smithsonian Institute and Lincoln Park Zoo were contacted because of their experience in the use of tracking devices (radio transmitters) on animals and fish for migratory research. This contact resulted in the application of RF tracking devices to a solution of the RF transmitter problems. The RF MOS presents a difficult problem area in that a submerged transmitter must be capable of transmitting through the water/air interface. The Wildlife Research Department of the University of Illinois (U of I) has been confronted with a similar problem in developing a small RF transmitter that has been implanted in fish. They have been confronted with the water/air interface problem and have had some success in coping with it. Mr. William Cochran, U of I researcher, appears to possess the state-of-the-art knowledge in this area. Several very useful points have arisen from his work. 1) He has found that a minimum of about 100 milli-watts is required to bring the signal out of the water. 2) Salt water exacerbates the problem. 3) In order to minimize interference, the transmitter output should be pulse coded. After conferring with Cochran on the RF transmitter, an effort was initiated to develop a unit with some of the basic system requirements of range, size, weight, and expense. The actual final layout and fabrication of the test units was done by Mr. R. M. Anderson, an associate in Cochran's company, Avondale Instruments, also in Champaign, Illinois.

2.2 Problem Review

This section summarizes and concentrates upon selecting the most foolproof methods for detecting a man overboard, conveying this event to shipboard, and providing means to thereafter locate the individual overboard.

It is next to impossible to devise a safety system which cannot somehow be intentionally by-passed. Therefore, prevention of suicide or murder have not been objectives of this study. However, protection for the inebriated, liesure time, or duty crewman is sought.

Although the application is for large vessels operating primarily on the Great Lakes, many facets of the problem and their solutions apply to inland waters (rivers) and to coastal and deep sea vessels.

2.2.1 Sensing Man Overboard/Transmitter Activation

Several reliable effects occur during the actual falling overboard event. Some of these effects have potential for use in developing the switching required (or activation of) the RF transmitter. As the transmitter is activated, the sensing of the man overboard should occur and be relayed to the appropriate stations aboard the vessel.

The events and effects that may offer potential for switching and also for supplementary means for alerting a man overboard situation are presented in Table 1. These are organized within four major headings which pertain to whether the effect occurred without mechanisms or devices (i.e., natural overboard and natural shipboard effects) or whether the effect occurred by use of instrumentation or mechanism (i.e., forced overboard effects and forced shipboard effects).

2.2.2 Discussion of Sensing and Switching Methods

Without lengthy discussion, most of the possibilities listed in Table 1 may be eliminated for obvious reasons. For system simplicity and reliability sensing of natural effects is preferred, and obviously, natural shipboard effects are preferred. It should be noted that the list of natural overboard effects holds several areas of promise; specifically acceleration, hydrostatic pressure effects, and water.

The magnitudes and durations of the first two of these effects is estimated in Figure 1 for two kinds of falls into the water from 16 ft (a 13 ft freeboard plus a 3 ft elevation for the body's center of gravity). As depth of water entry is difficult to calculate for dives, it was estimated from swimming pool safety requirements for pool depth vs. diving platform height. The depth of prostrate entry was then estimated by scaling to the increased body area presented to the water's surface. The constant slope plot of velocity during free fall is calculated, but the constant slope during deceleration in water is an estimation. As water drag is proportional to velocity squared the following curves of omnidirectional acceleration become peaked as shown at impact, then trail off to the one "g" of gravity. The one "g" of gravity is absent during the free fall. The last plot shows gauge pressure corresponding to the hydrostatic pressure at each water depth as it occurs.

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TABLE 1. RELIABLY OCCURRING EVENTS AND EFFECTS FOR THE MAN OVERBOARD SITUATION

Natural Overboard Effects:

Free Fall:

- reduced acceleration (low g)

Physiological changes:

- adrenalin
- blood pressure
- heart rate
- respiration
- etc.

Water Entry:

- dissolving medium present (tablet switch)
- floating medium present (caged float switch)
- electrical conductivity change (water switch)
- thermal conductivity change (air vs. water)
- acceleration changes (zero "g" then impact)
- pressure changes (hydrostatic)
- impact pressure waves in water

Natural Shipboard Effects:

- mass loss (infinitesimal percentage)
- possible witness

Forced Overboard Effects:

- radio signal in freeboard region (personal transmitter)
- magnetic field change in freeboard region (personal magnet)
- dye or particle release in water
- chemical release in water (ion diffusion)
- sonar signal in water (active belt)
- explosive signal in water (squibs)
- flashlight in water

Forced Shipboard Effects:

- detect natural overboard effects listed
- detect forced overboard effects listed
- detect IR source in freeboard region (body heat)
- detect body in freeboard region (electric eyes)

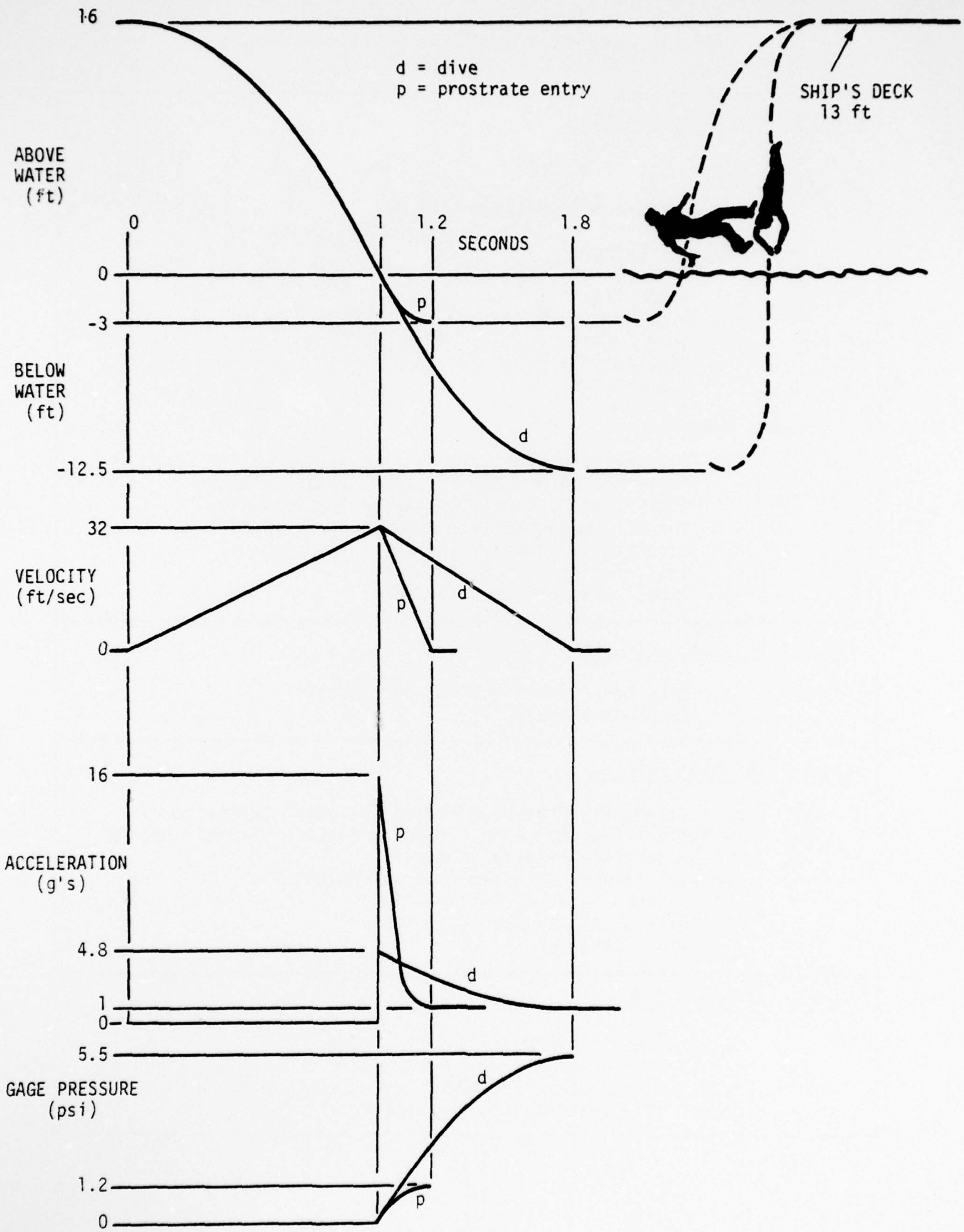

FIGURE 1. ESTIMATES OF THE PHYSICAL PARAMETERS IN A CREWMAN'S FALL FROM A 13 FT FREEBOARD

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Essentially the figure shows the following facts about a fall overboard that can be used in the development of a switching mechanism on the transmitter.

1) The crewman falling prostrate will submerge after entry into the water approximately 3 ft below the surface; the crewman entering the water in a dive configuration will submerge after entry into the water approximately 12-1/2 ft.

2) The maximum velocity of the fall will be 32 ft per second and will be the same for either configuration.

3) As would be expected, the deceleration in water for the prostrate entry is estimated at 16 g's; deceleration in water for the diving entry is estimated at 4.8 g's.

4) Gauge pressures for the relative depths below the surface for each of the falls overboard is 1.2 psi for the prostrate entry (depth of 3 ft) and 5.5 psi for the diving entry (depth of 12-1/2 ft).

One consideration for use of an omnidirectional accelerometer on the individual is that it would indicate one second of zero acceleration followed by a peak acceleration of at least 4.8 g's. But a false indication might well occur when crewmen descend shipboard ladders by using the ladder rails only to guide their descent. Discrimination against such false accelerometer indications would be difficult.

The hydrostatic pressure effect seems quite unlikely to occur in any other normal crew activity. Based upon present fall and submerging alternatives, it offers one of the best possibilities for the natural non-ambiguous overboard effects to consider for switching.

2.2.3 Location of Man Overboard

Once a man overboard event is identified, some means to locate him is mandatory. Systems which require active participation by the victim must be de-emphasized since he is often immobilized by fear or shock. The quasi solution of putting a location device (beacon) overboard immediately during the fall or after the fall in the vicinity of the victim has great advantages, particularly if combined with flotation for the victim. With a sea anchor deployed, the latter beacon could well bring search equipment within range of the smaller beacon on the victim.

For precise location the victim must also carry some alternative form of location equipment on his person. Alternatives here are used in the broadest sense and encompass all kinds of signals or indications for location. Some possibilities are:

- light
- dye or particles in water
- sonar source
- radio source
- IR source
- flag
- radar reflector
- ion diffusion in water
- signal rockets
- exploding squibs

Most of these alternatives can be eliminated because night and day effectiveness from one location unit is needed. It may be assumed that size and wearability would be effected if two simultaneous possibilities were employed in one unit. More alternatives are eliminated because of their poor effectiveness in high waves. Still others are eliminated because of their bulk.

A valuable characteristic of water is that it may be used as a transmission medium for sound signals; either coherent (sonar) or impulse (squibs). A regular but slow sequence of small exploding squibs on the victim's belt might provide the location function without permanent injury to the victim. However, the use of squib containing belts offers problems of wearability and interference with tasks on deck. Other than explosive means to propagate such impulses into the water are therefore needed. The broad frequency spectrum for sonar signals may solve the problems that surface waves and body "shadows" could cause with coherent sonar.

The victim could be located by using the water medium to spread a dye that fluoresces when either naturally or artificially illuminated. Such a system might also allow conveying the event shipboard by continuous monitoring of the ship's backwash for the fluorescent re-radiation (when underway) or monitoring waterline (while at dock). A sensor with suitable selectivity for the characteristic re-radiation is probably achievable. Instead of a fluorescent dye, dispersal of particles or chips both buoyant and fluorescent might be even more efficient, as more of the material would then be at the water surface.

Because the victim is almost completely submerged, the water itself may be the best medium for signaling. Partly as a result of this project it is now known that radio radiation from beneath the surface can be accomplished if the antenna is not in direct contact with the water.

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2.2.4 A Vehicle for Man-Worn Devices

The wearing of some element of the MOS by crewmen seems unavoidable. It is apparent that the unit and mode of attachment must be convenient to encourage acceptance and use by the crewmen. At least five such vehicles are considered. These are presented in Table 2.

TABLE 2. VEHICLES CONSIDERED FOR MAN WORN MOS DEVICES

Vehicle	Remarks
belt	... wearing difficulty for some regular crew tasks
modified flashlight	... poor attachment, but power advantage
wrist band	... wearing easily confirmed but inconvenient for wearer
neck lanyard	... dangles in way - may entangle victim in water
shoes	... units are not interchangable among persons

2.2.5 Energy Sources

If an active location beacon is worn by the victim, several compact energy sources are possibilities for powering them:

- batteries
- compressed gas (CO_2)
- chemically generated gas
- chemically generated heat

Selection of the energy source is dependent upon the beacon output and size requirements. At this time, batteries are considered a prime alternative for a prototype MOS unit.

2.2.6 System Checks and Use Enforcement

Without dwelling upon the obvious, a few comments are in order concerning system checks and use enforcement. A well-designed system will be accepted by a ship's crew if it does a needed job. However, the system will need periodic checks and tests of its operational elements. It is especially important that parts of the system to be worn on the crewmen's person must be checked occasionally both for possible damage during use and for proper operating condition. Inspection during

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crew muster for "fire and life boat drills" seems a good alternative for this check. These are supposed to be conducted once a week on a ship and in the case of more than 25% crew change, a drill must be held within 24 hours after leaving that port.

2.2.7 Frequency of Usage

A major consideration in selecting and designing any system must be its frequency of usage. In this case the frequency of occurrence of the man overboard situation offers some problems. The usage effects several considerations including the human response to the overall system, the system reliabiltiy, and its cost.

Previous observation has shown that safety and alarm systems which are infrequently active are likely to be ignored or disbelieved. Recognition and acceptance of such an alarm with any confidence offers a significant problem. Experience with fire, smoke, combustible gas, and burglar alarms exemplify this principle. Further, if the relative incidence of false alarms is appreciable or if the system causes inconvenience, the system may actually be deactivated or turned off (e.g., night-time alarms from weather alert receivers), or by-passed (e.g., automobile seat-belts).

Infrequent usage of a system also adversely affects system reliability and cost. As a case in point consider the military missiles in underground silos which must reliably operate ten years after installation. In order to achieve this, all monitoring systems are redundant and are exercised or tested on a regular schedule. A high cost to achieve reliability in these missile systems is inherent.

The anticipated frequency of usage of the MOS for actual emergencies is quite low. Of data available (Reference 3, pg. 41), 36 men fell overboard from Great Lakes vessels from the year 1968 to 1972. There were no recoveries of live victims for those men falling overboard while the ship was underway (14 fatalities). Eleven of 22 men were recovered from falls overboard while the ship was at the dock.

A general idea of the expectancy for a man overboard situation can be estimated using the above statistics and the appropriate number of American vessels regularly running in the Great Lakes. Seafarers International Union reports there are approximately 120 documented vessels to which this decision would apply.

Assume that on the average, 7.2 men fall overboard per year (i.e., 5 years divided into 36 men overboard) for the 120 plus vessels. This can be further interpreted to mean that a particular ship would average a man overboard situation every 16.7 years (i.e., 7.2 divided into 120 vessels). Sufficient to say that because there is a low number of actual man overboard situations for any given ship over a period of time, it is unlikely that such an emergency will be expected for any one year by a given crew. Consequently, the MOS must have extremely high reliability in order to function believeably to elicit the appropriate crew action when the man overboard situation actually occurs.

2.3 Special Considerations for Man Overboard Situations

In the partial factor tree shown in Figure 2, there are at least eight baseline factors that could lead to man overboard scenarios. In addition, another factor could be added such as rough or calm sea conditions, adding to a total of fourteen baseline set of factors that could lead to scenarios. Examining a simplified baseline such as No. 1 where the vessel is operating in daylight at full speed (probable maximum for a vessel at 15 knots) in calm seas, some interesting facts emerge pertaining to the MOS.

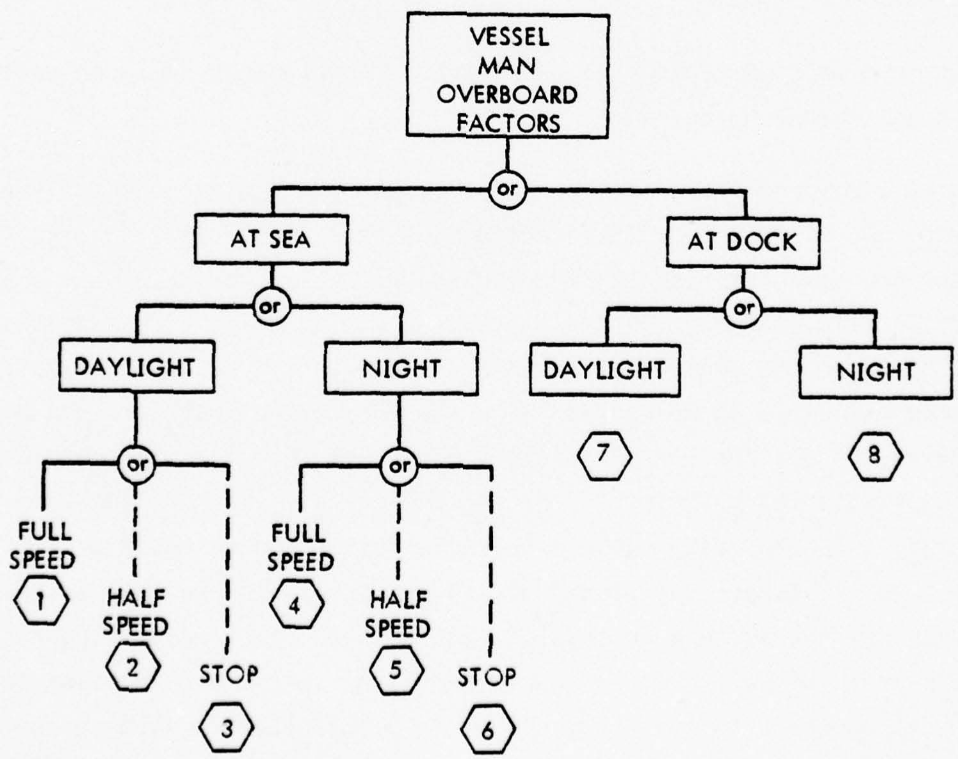

FIGURE 2. MAN OVERBOARD FACTOR TREE WITHOUT FACTORS OF SEA CONDITIONS

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Suppose, for example, one man falls overboard and is seen by another crewman, a "natural shipboard effect." A survival system profile without a detection/location system for these conditions is shown in Figure 3. Note that the elapsed times (and distances) for the occurrence of the events of the system encumber successful recovery of the victim. Additional analysis of the profile suggests that the following events will occur.

1. The closest piece of survival gear will be the throwable life ring in water if the victim is seen falling overboard or in the water. This will likely be 500 feet from him.
2. The closest survival system and the only one likely to be visible is the ship itself.
3. The ship is approximately half-mile away before the command can be given to stop or turn around.
4. The ship is a half-mile away before systematic visual search for the victim can be initiated.
5. The only crewman who saw the accident probably lost visual contact with the victim soon after throwing the life ring. There is great difficulty in keeping the head portion of the victim in sight for any appreciable distance or time.

Additionally, the problem could have been further complicated by rough weather and night operations (baseline No. 4).

Figure 4 shows a comparable partial survival system profile for the man overboard situation with the MOS. It should be noted that the time of initial detection of the man overboard has been reduced from 120 seconds to approximately five seconds with the MOS in this example. Figure 5 provides the specific time comparison (with and without MOS) for the vessel to initiate the return to the point where the man went overboard. In this example, even with the MOS, approximately seven minutes will be required to get the vessel in the vicinity of the victim to make a recovery. This indicates the severity of the man overboard situation involving any vessel underway. Due to vessel-unique characteristics, the example presented was only intended to illustrate the plight of the man overboard and to show that an MOS in itself does not guarantee a successful victim recovery. Considering that ore carriers, tankers, LNG carriers, and container ships to include deep sea vessels have unique characteristics and every effort should be made to develop the best overall MOS. This MOS should transcend the individual vessel differences and

	EVENT #1	EVENT #2	EVENT #3	EVENT #4	EVENT #5
	MAN FALLS OVERBOARD	IF THE FALL OVERBOARD IS WITNESSED, CREW-MAN DECIDES WHICH THROWABLE LIFE RING IS CLOSEST - RUNS FOR IT AND THROWS IT OVERBOARD TOWARD VICTIM	CREWMAN RUNS TO SHIP'S INCOM SYS. & CALLS BRIDGE OR "MAN OVERBOARD" IS SHOUTED MAN TO MAN TO THE BRIDGE (OR A COMBINA-TION OF THE TWO)	MAN OVERBOARD ALARM OR "GENERAL QUARTERS" SOUNDED AND ENGINE ROOM PERSONNEL ARE ALERTED FOR ENGINE COMMANDS	WATCH RUNS TO APPROPRIATE SIDE OF VESSEL AND RELEASES OTHER LIFE RING WITH SMOKE SIGNAL OR LIGHT; ALSO CONFIRMATION OF SIDE MAN HAS FALLEN FROM
ELAPSED TIME (Seconds):	0 sec.	10 to 30+ sec.	90 sec.	100 sec.	120 sec.
VICTIMS DISTANCE FROM SHIP (Feet): SPEED @ 15 KNOTS	0 ft	500 ft	2300 ft	2500 ft	3000 ft

FIGURE 3. SURVIVAL SYSTEM PROFILE FOR MAN OVERBOARD SITUATION <u>WITHOUT MOS</u>

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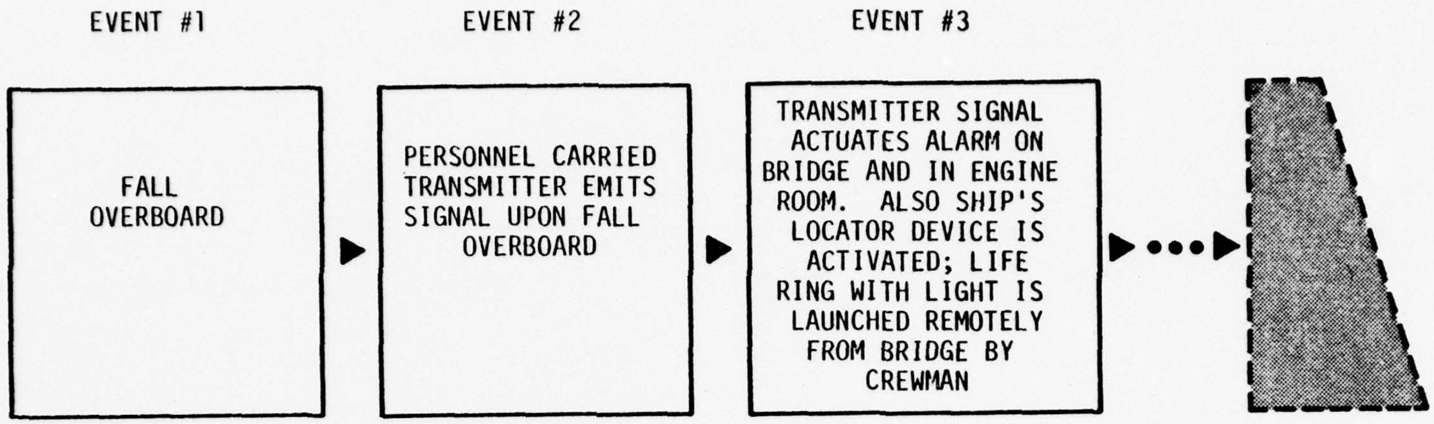

ELAPSED TIME (SECONDS	0 sec.	2 sec.	5 sec.
VICTIMS DISTANCE FROM SHIP (Feet)	0 ft	50 ft	125 ft

SPEED @ 15 KNOTS

FIGURE 4. PARTIAL SURVIVAL SYSTEM PROFILE FOR MAN OVERBOARD SITUATION WITH MOS

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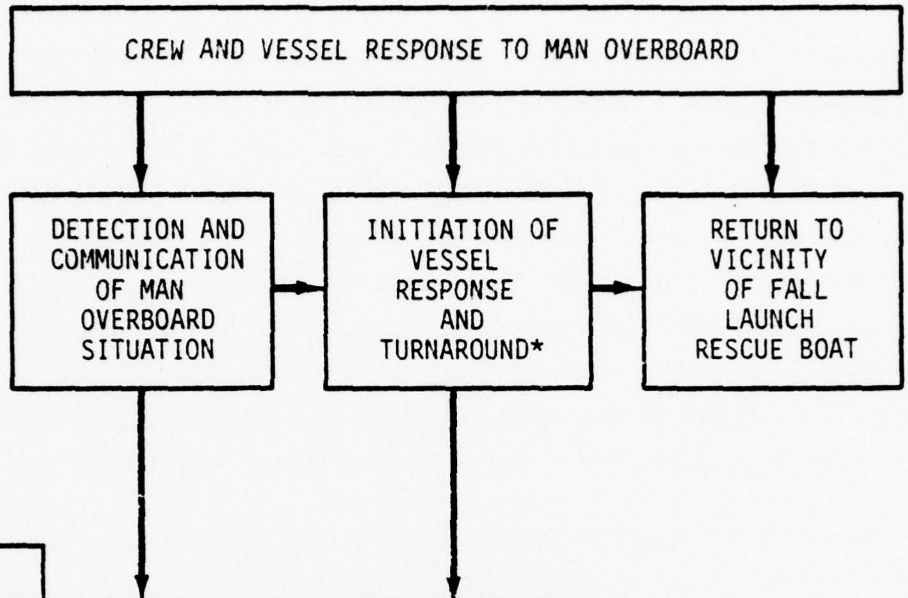

MOS CONDITION		
WITHOUT MAN OVERBOARD SYSTEM	100 SECONDS (PER FIGURE 2)	APPROXIMATELY 120 SECONDS
WITH MAN OVERBOARD SYSTEM	2 SECONDS (PER FIGURE 3)	APPROXIMATELY 5 to 10+ SECONDS

* The Williamson Turn is usually recommended for this situation and most applicable in open seas. This procedure is not always applicable to narrow channels and/or shallow intercoastal waters where ship's draft may exceed water depth outside of established channels.

FIGURE 5. PARTIAL SURVIVAL SYSTEM PROFILE COMPARISONS WITHOUT AND WITH MOS

provide the maximal assurance that the victim will be detected upon entry into the water and located/tracked with respect to recovery and rejoining the vessel.

Obviously, the vessel speed, vessel location in shallow water, turning radii, stopping distance, crew reaction time, and a host of other factors determine the time duration that the victim must survive on his own. Dayton (Reference 4) has estimated that after the man overboard alarm has sounded, an estimated 25 minutes is required to recover the victim. Dayton's work showed the possibility of reducing the total time if the lifeboat is readied for launch prior to the ship's stopping. With a well drilled crew, he estimates the time could be reduced to 17 to 18 minutes, but without some form of flotation device and thermal protection in cold water all eleven of the casualty cases in the Dayton study would not have survived. His work emphasizes the requirement for quick recovery of the victim.

Baum, et al, in a later report (Reference 2, pp. 52-55), provides some interesting data regarding man overboard casualties. In five instances, the actual time of the man in the water was given. The average time was six minutes. Four of the five victims were lost. In another eighteen examples where the rescue was started immediately but the time in the water was unknown, eleven of the eighteen victims were lost. This is additional support that successfully retrieving the victim without loss of life is a time dependent process, and that the time interval must be minimized.

While the MOS can shorten some of the time of these activities, it cannot guarantee recovery. W. R. Keatinge, author of "Survival in Cold Water," (Reference 3) states that cold is responsible for most deaths in water rather than drowning. The water temperature in the cases to which Keatinge is referring averaged a little over 40°F. His report of the analysis of wartime sinkings of merchant ships showed a 45% fatality rate for ships that sank in waters from 40° to 48°F. There was only a 27% fatality rate for ships that sank in waters from 68° to 88°F. It should be noted that these deaths resulted from several causes.

Keatinge's research shows that death from hypothermia is not unique to extremely cold water. The sinking of the Lakonia took place in relatively warm water (65°F) where the sea was fairly calm and in good weather. Rescue ships searched the area the first day and found 113 people floating dead in their life jackets. There was clear evidence that hypothermia was responsible for most of the deaths. The obvious implication here is that the colder the water, the less time can be allowed for rescue for a man overboard.

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There are a number of variables that determine the duration of time a man can survive in the water while awaiting rescue. These include water temperature, air temperature, the individual's degree of obesity, personal flotation devices (both to keep the victim afloat and to provide some protection from body heat loss), temperature of the water, and victim's general physiological and psychological status. Rough data estimates show that the maximum time allowable for recover of a man in cold water is around ten minutes. An estimated time for detection with MOS (see Figure 4), vessel turnaround, and return to vicinity of fall would be about seven minutes (vessel at 15 knots). Allowing another minute or two to recover the victim pushes the total recovery time to around ten minutes. At best, recovery of a live victim would be marginal under the conditions described and practically hopeless if Dayton's estimate of 25 minutes <u>without the MOS</u> would be the actual recovery time (Reference 4).

In summary, the MOS should be considered only one element in an overall survival/rescue system which includes a personal flotation device, thermal protection, and a lifeboat or rescue craft.

2.4 Some Existing (Available) RF Equipment Compared to the MOS

There are several types of commercially available devices designed to utilize the RF location features. They currently are marketed as Emergency Position Indicating Radio Beacons (EPIRBs) and as Emergency Location Transmitters (ELTs). EPRIBs are actually marine versions of ELTs. The latter are now required on all general aviation aircraft. Although the EPIRBs have a different mission than a Man Overboard System (MOS), the technology is similar. The EPIRBs are primarily for vessels beyond the twenty mile range of the VHF radio transmission. Most likely, EPIRB signals will be picked up by an aircraft overhead. The MOS signal, on the other hand, is for alarm actuation at the water surface level and for homing or location.

Stapleton (Reference 5), states that humidity, salt, and heat of the marine environment cause severe problems with the EPIRBS. For example, condensation and moisture have inadvertently actuated these devices. While no figures could be obtained for the United States, Canada's Ministry of Transportation reported 23 false EPIRB alarms in 1975, all caused by moisture in the electronic circuitry. This is an intolerable failure mode for the MOS transmitter and suggests a need for advancement of the technology used for these devices.

The typical EPIRB with built-in flotation is approximately 15 inches in length, 3 inches in diameter, and weighs more than three pounds. It has maximum range capabilities of up to 250 miles from aircraft altitudes, and a continuous operational life of 100 hours. This type of device is inappropriate for the needs of the individual crewman, but, system-wise, has some similarities to the MOS concept. A partially satisfactory or quasi-MOS could be assembled from selected off-the-shelf EPIRB components. Such a system would consist of an EPIRB device (transmitter) and direction finder device on board the ship, conceptually illustrated in the block diagram of Figure 6. By replacing the EPIRB in Figure 6 with the MOS transmitter, the diagram is applicable to the MOS.

2.5 MOS RF Hardware and Design

For the MOS having maximum value for the crewman, the volume/size goal for the transmitter package is under ten cubic inches (1" x 2" x 2"). The device could be attachable to a crewman's belt or pocket edge and worn much in the fashion of a roll-up metal tape measure. The geometric envelope for the transmitter is shown in Figure 7. In this conception of the MOS, the transmitter must be able to transmit a receivable signal when submerged two to three feet below the water surface. Ideally the device should have some means for reassuring the victim that it is operating when he is in the water. One alternative method would be a light that flashes continuously while the transmitter is in operation, i.e., in a transmitting mode. Figure 8 shows the belt worn transmitter concept in the actual man overboard condition.

As an alternative approach to the same concept, the transmitter subsystem of the MOS could be designed for self-buoyancy. The unit would be attached to the belt clip by means of a lanyard. Once in the water, the transmitter would float and the antenna would be out of the water much in the fashion of the EPIRB devices. This would provide some solution to the problem pertaining to the power required for the signal to transmit with strength beyond the water-to-air interface. This concept is illustrated in Figure 9. However, it has a definite drawback in that the lanyard could become entangled once the man is in the water and prevent him from treading water or swimming to a ring buoy. There is always the possibility that the victim could hold the transmitter on the surface once he has reached some flotation. But it must be remembered that it is unlikely that the crewman will be able to assist himself, at least not without thorough preparation and training. From the human factors aspect, the fixed belt worn transmitter has great appeal for the reasons mentioned.

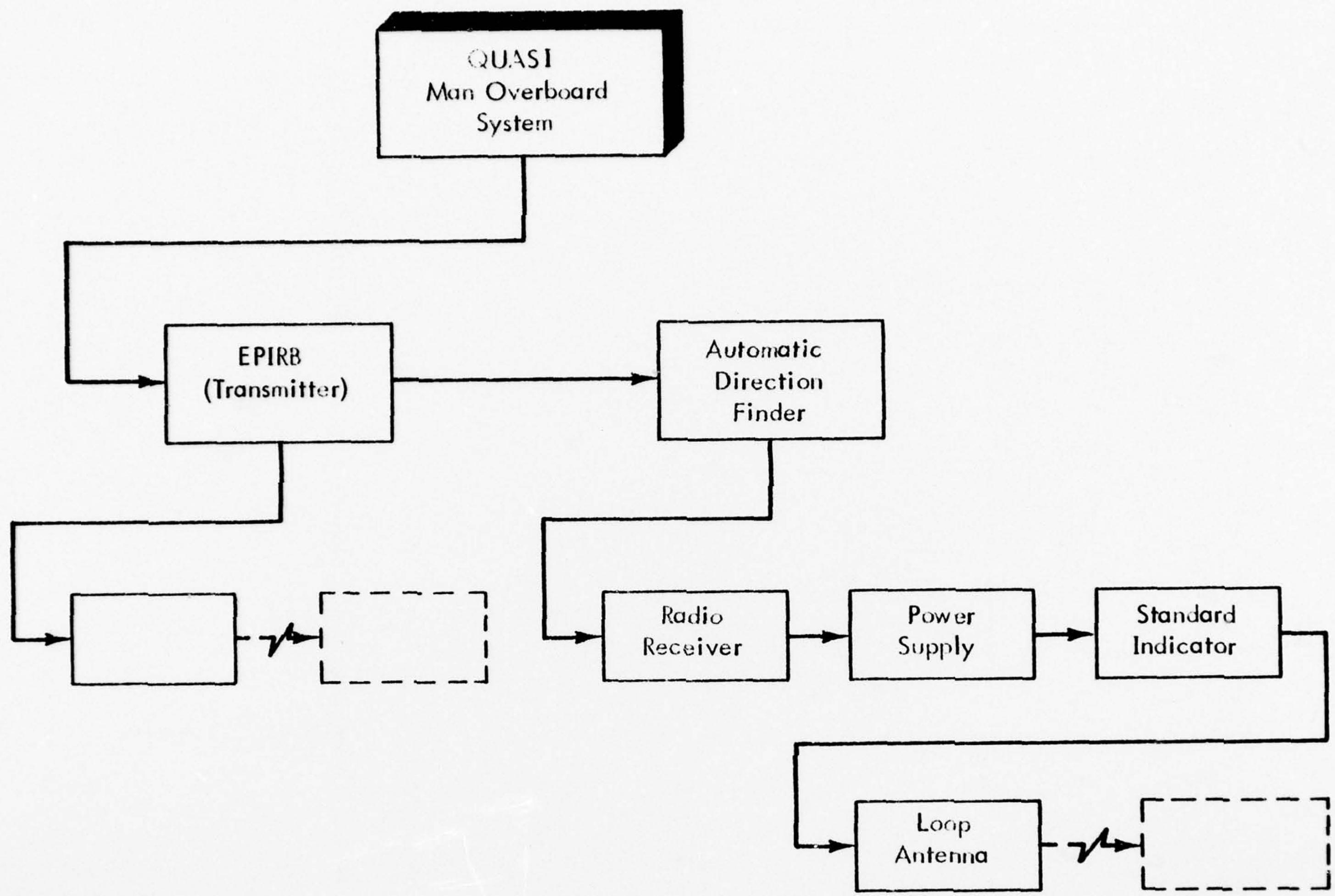

FIGURE 6. QUASI MOS CONCEPT DIAGRAM

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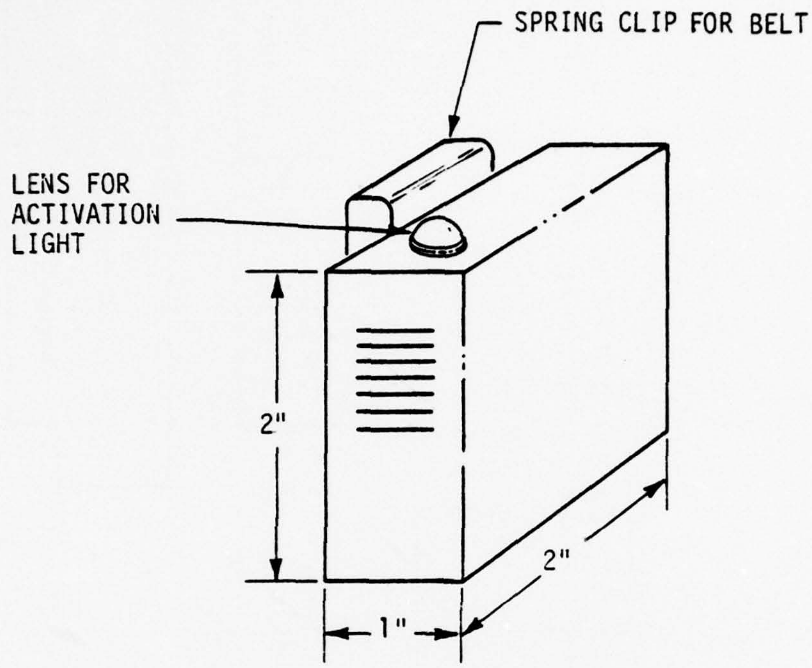


FIGURE 7. TENTATIVE SIZE ENVELOPE FOR BELT WORN MOS TRANSMITTER

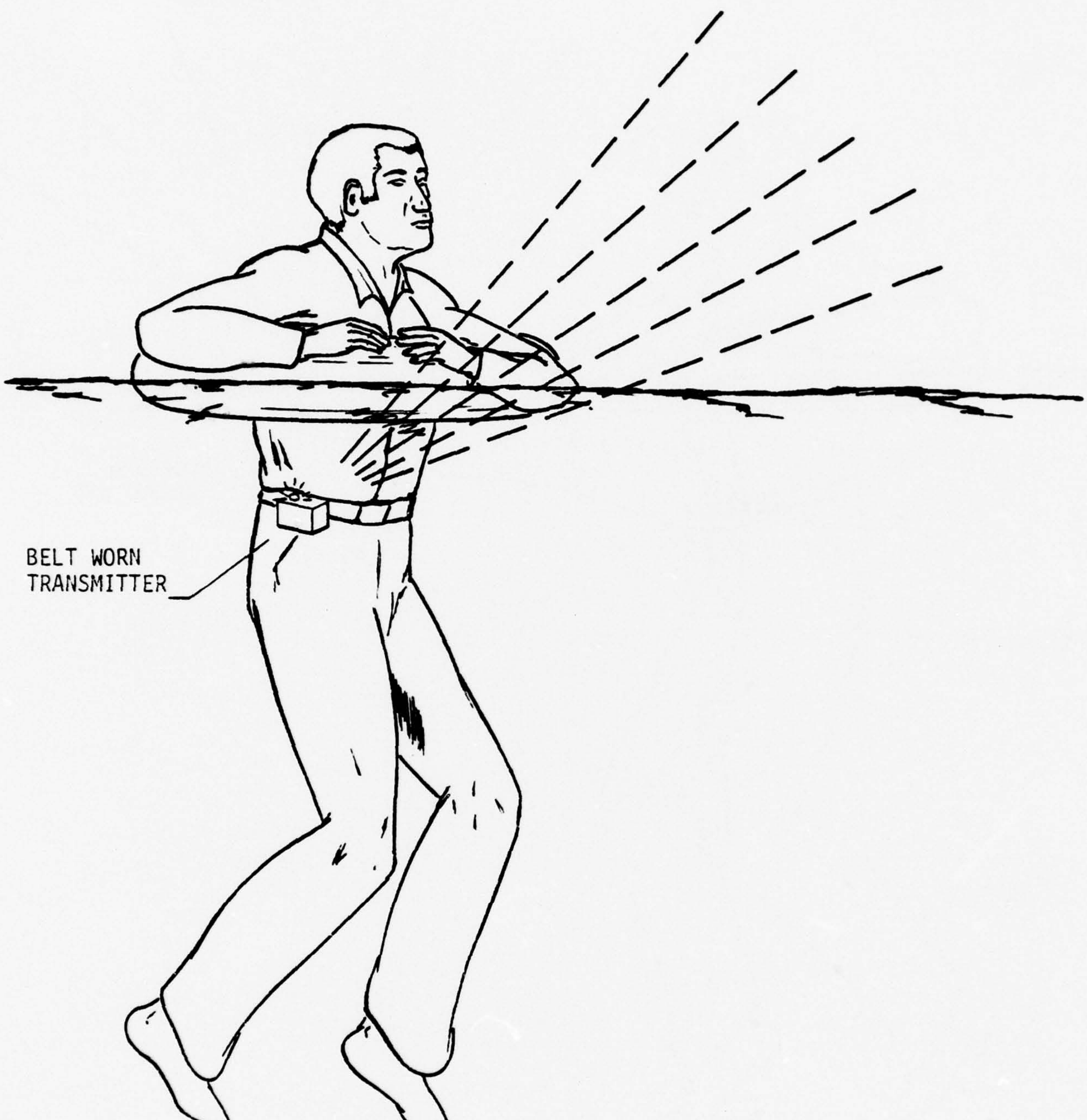


FIGURE 8. BELT WORN TRANSMITTER CONCEPT WITH TRANSMITTER FIXED TO SPRING CLIP

(27)

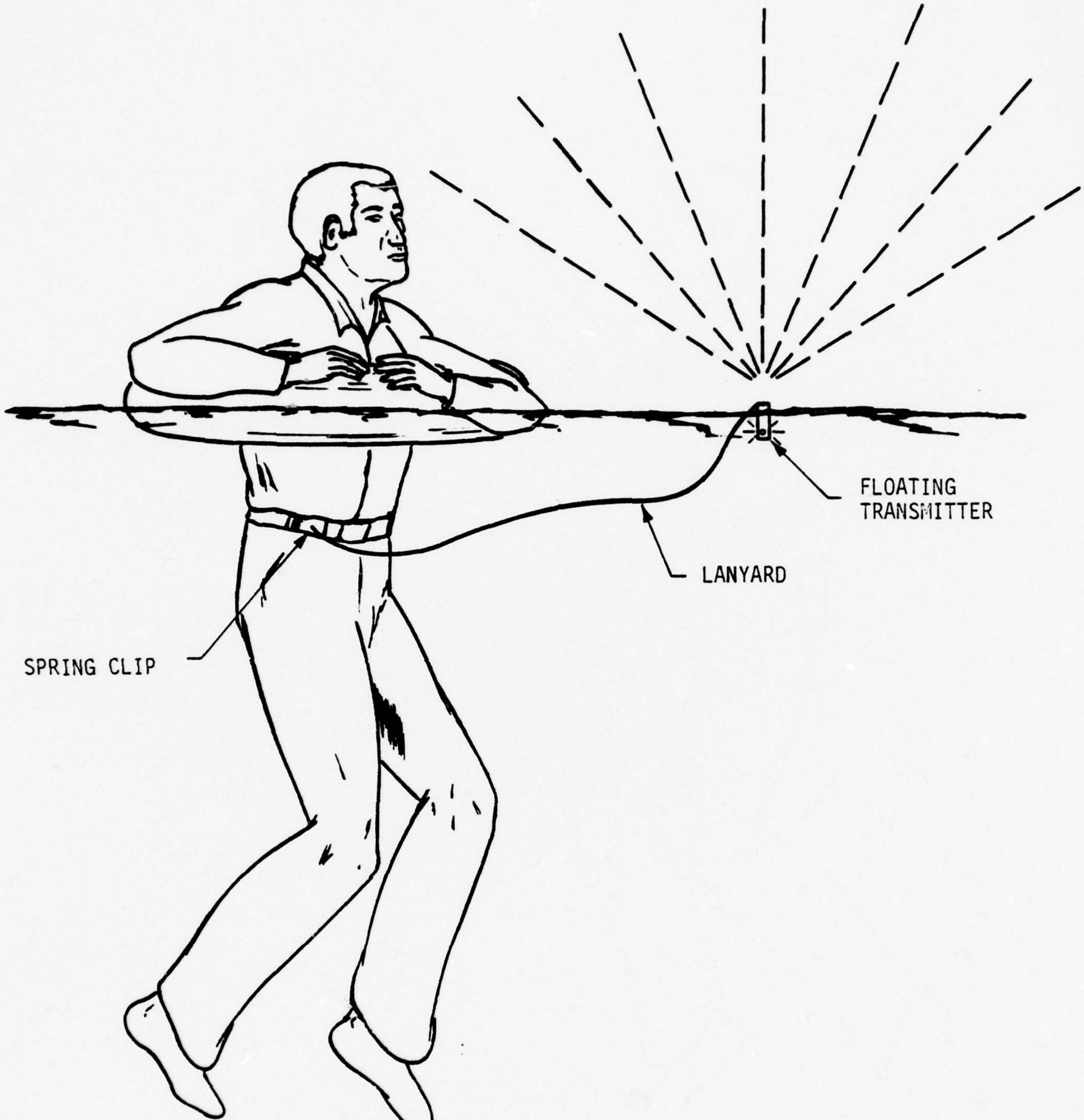


FIGURE 9. BELT WORN TRANSMITTER CONCEPT WITH FLOATING TRANSMITTER AND LANYARD ATTACHMENT TO SPRING CLIP

(28)

2.6 Considerations for Sonar for MOS

The use of a sonar device presents formidable problems. First, any sonar type device is required to have an underwater sensor (receiver). Secondly, the use of a personnel worn transmitter appears too cumbersome since the transmitter would probably be rather bulky and the power requirements would be relatively high when compared to an RF type transmitter. Thirdly, the sonar signal may have to penetrate the victim's body to eliminate shielding when the body is between the transmitter and the ship. Finally, since a sonar device is, by definition, a "sound" device, it senses and responds to any sound source and may respond to ship noise.

During the conduct of this project, one device was found which appeared small enough to provide some promise. This device is manufactured by Sound Wave Systems, Inc. and is marketed under the trade mark WET BEACON/WET FINDER. The two separate units are used by divers to 1) mark the location of an underwater object (WET BEACON) and 2) to locate the object (WET FINDER). Each unit is 2 in. x 6 in. and weighs about 2 lbs.

The Beacon produces an omnidirectional pulsed tone underwater while the Finder is a directional receiver. If the Finder is pointed toward the Beacon, a small light is actuated; pointed away from the beacon the light extinguishes. The range of the unit is advertised to be approximately 1,000 ft. However, Wyle purchased one unit and found the usable range to be considerably less...about 700 ft. It was also found that the Finder is sensitive to such sources as motor boat noise. Wyle abandoned further work on the sonar approach and concentrated on the RF system once contact was made with Cochran and Avondale Instruments.

3.0 THE RF SYSTEM HARDWARE DESCRIPTION

The specifications dictating the design to the builder of the RF MOS transmitter were as follows:

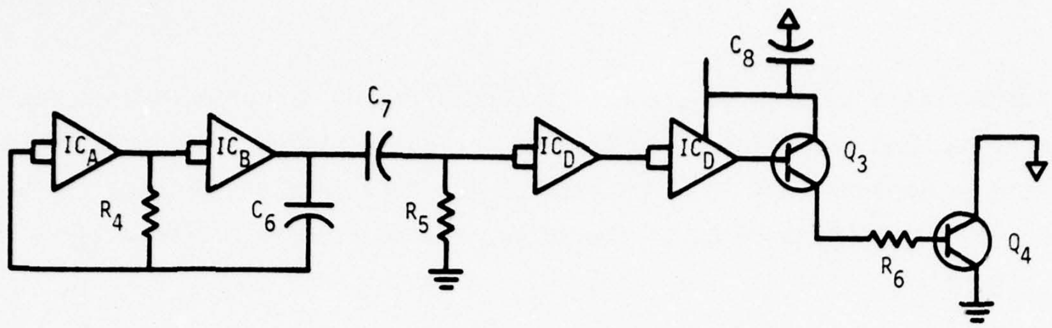
1. Transmitter: Pulsed continuous wave (CW) signal
2. Size: 2 in. x 2 in. x 1 in. to 3 in. x 3 in. x 1 in. maximum
3. Weight: 8 oz.
4. Turn-on: By immersion in fresh water or salt water (or other)
5. Buoyancy: neutral or positive
6. Operating Hours: 12 hours minimum on self-contained batteries
7. Operating Range: Nominal one (1) mile when submerged at belt level in salt water or fresh water
8. Possible lanyard attachment between clip and transmitter.

The prototype transmitter for testing was designed and built by William Cochran and M. Anderson of Avondale Instruments located in Champaign, Illinois. Three radio transmitters were fabricated which operated at frequencies of 14.960 mHz, 26.760 mHz, and 37.600 mHz. The three transmitters are basically the same with minor variations in component values due to the different transmitting frequencies. These frequencies were selected to verify the effects of different operating frequencies on transmitting range with respect to the water-to-air interface and antenna size. For example, it was anticipated that the higher frequencies would more likely have greater range than the lower frequencies given the required small size of the antenna loop. However, the lower frequencies were more likely to have greater penetration of the water-to-air interface. All of these frequencies were within the receiving band of the receivers and spectrum analyzer used for demonstration.

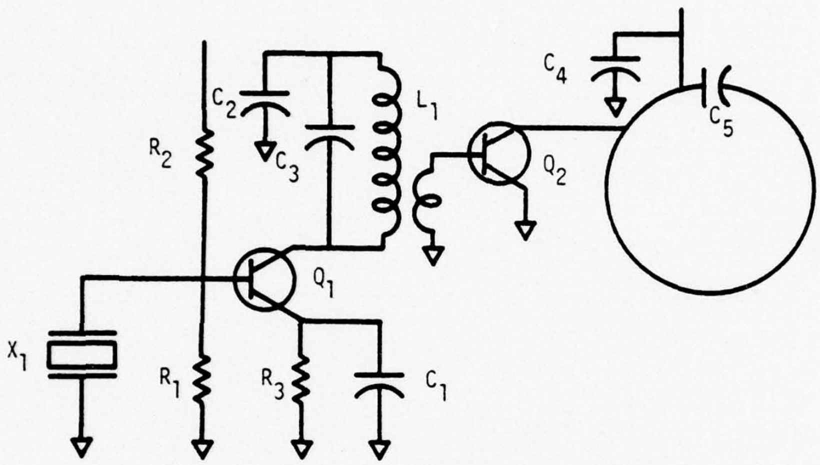
Hardware used for construction of the transmitter were "off-the-shelf" components. Avondale Instruments personnel believed that the output of the system could be greatly improved by using "matched components" in the transmitter. However, the purpose of this project was limited to demonstration of the feasibility of the RF MOS. Once this was established, then refinements of the hardware and methods can be undertaken. The use of "off-the-shelf" components necessitated an increase in size of the RF transmitter to 3 in. x 3 in. x 1 in. to accommodate a larger loop antenna.

The transmitter is a 100% solid state unit consisting of two primary circuits: 1) the RF generator and amplifier circuit, and 2) a *pulse timing circuit*. The two portions are shown in Figure 10. A sketch of the layout of the printed circuit is shown in Figure 11. Photographs of the actual tested prototype transmitters are shown in Figure 12.

(31)



PULSE WIDTH AND TIMING



RF GENERATOR AND AMPLIFIER

<u>COMPONENT VALUES OF PRIMARY CIRCUITS IN THE PROTOTYPE MOS TRANSMITTER</u>

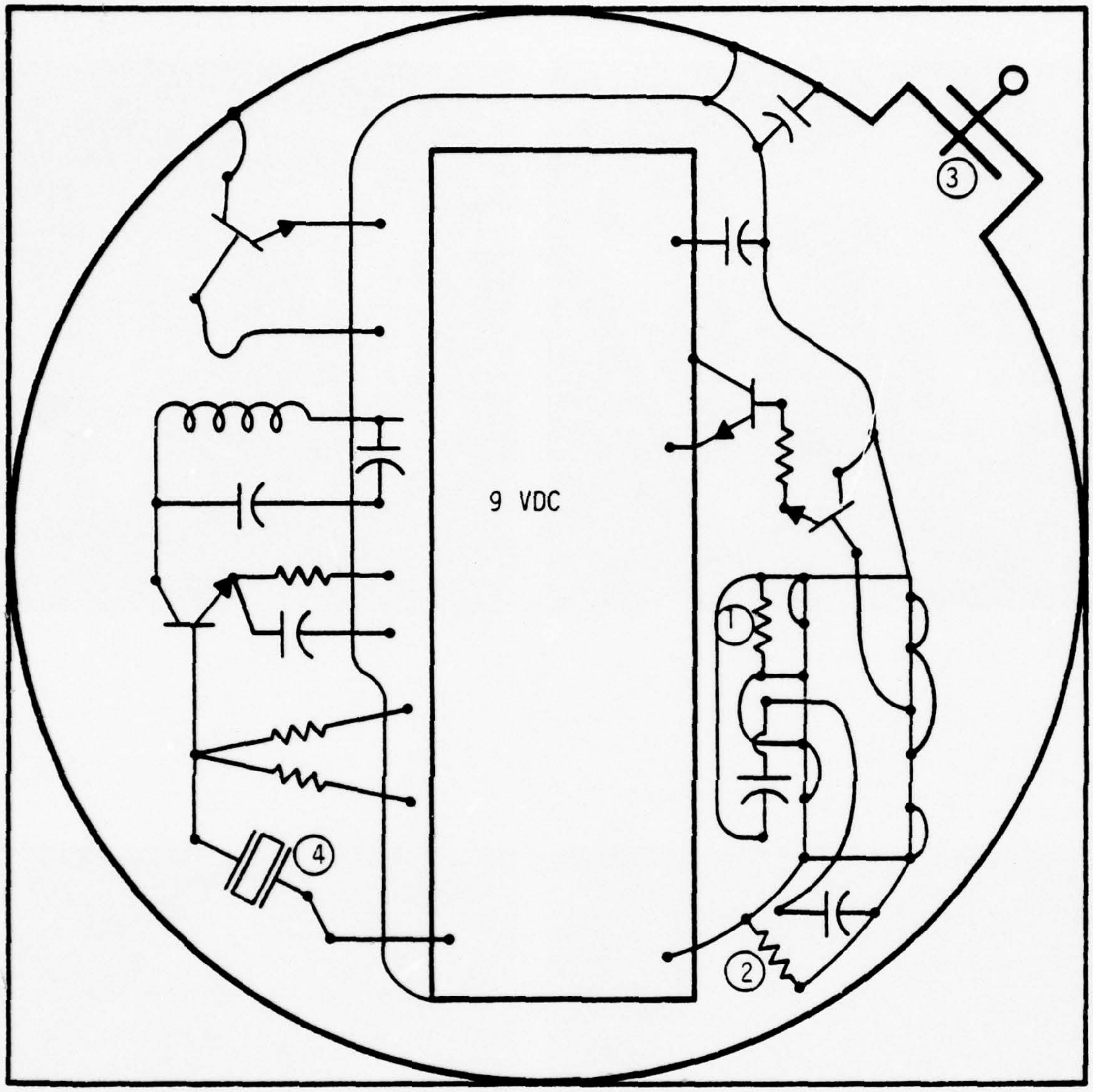
R_1 = 3.3 K
R_2 = 15 K
R_3 = 100 Ω
R_4 = 100 K - sized for repetition rate
R_5 = 100 K - sized for pulse width
R_6 = 430 Ω

C_1 = 150 Pf
C_2 = .01 - .05 (ARCO 402)
C_3 = 4.7
C_4 = .01 - .05
C_5 = (ARCO 423) - sized to resonate loop at the operating frequency
C_6 = .47
C_7 = .04
C_8 = .005

Q_1 = ECG 123A
Q_2 = ECG 235
Q_3 = ECG 123A
Q_4 = ECG 128

IC = RCA CD4001AE
Crystal = As desired

FIGURE 10. LAYOUT OF THE TWO PRIMARY CIRCUITS OF THE MOS TRANSMITTER PROTOTYPE



1. Size to establish desired repetition rate
2. Size to establish desired pulse width
3. Size to resonate loop at operating frequency
4. Crystal selected based on third overtone frequency

FIGURE 11. LAYOUT OF THE PRINTED CIRCUIT BOARD OF THE MOS PROTOTYPE TRANSMITTER

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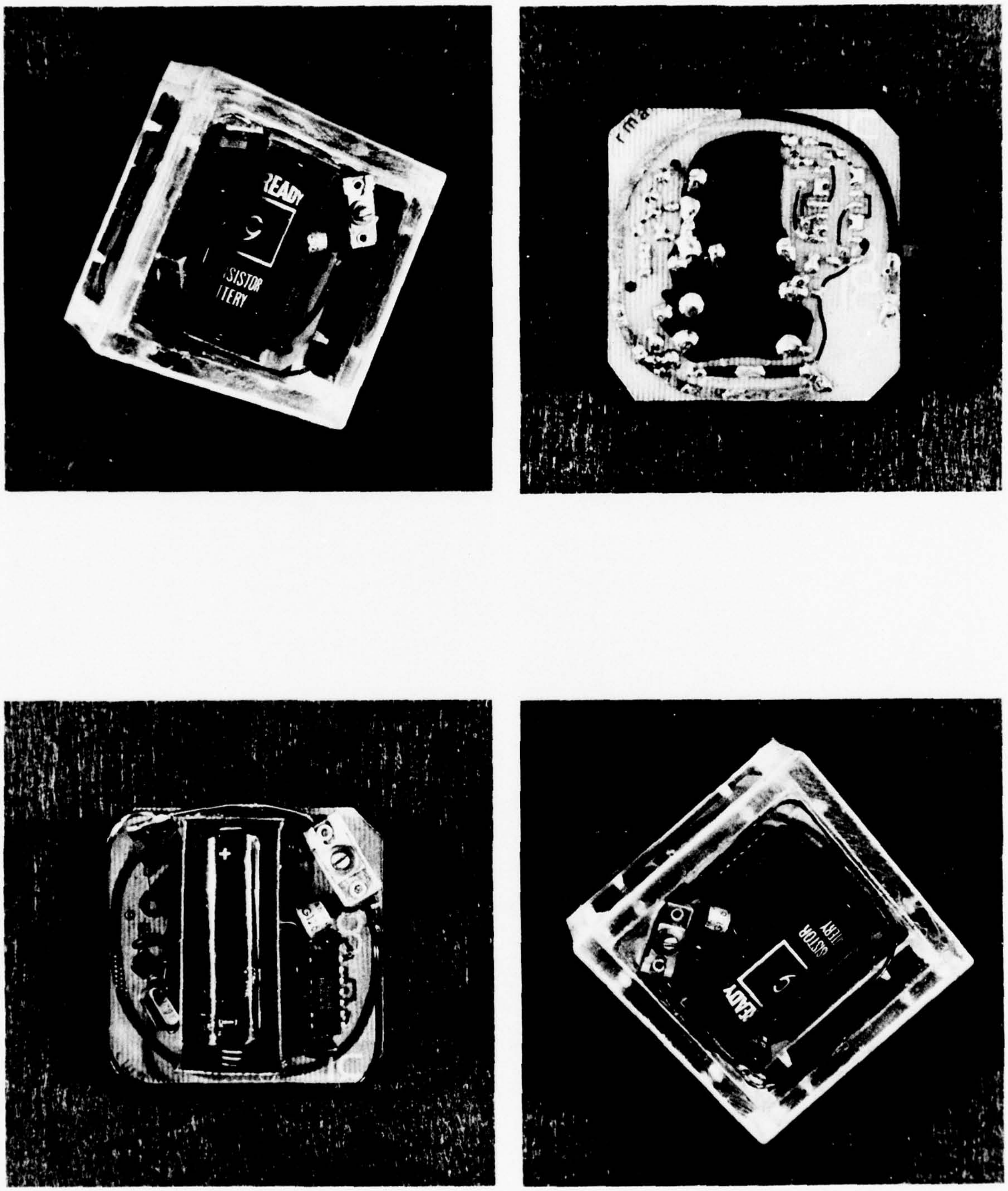

FIGURE 12. PHOTOGRAPHS OF PROTOTYPE MOS TRANSMITTER

Neg Furnished

neg furnished

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4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Discussion of Conclusions

Based on the results of this feasibility study, it appears that the concept of a man-worn, small, lightweight transmitter is quite necessary and feasible. This transmitter can function as both detector and locator for a man who has fallen overboard. It is well within current technology to have the transmitter signal automatically alert the crew and to provide a homing signal for recovering the victim.

The results of the tests conducted are presented in Appendix A. The following items indicate clearly:

- A very small, lightweight underwater RF transmitter can be designed which will be useful when submerged to depths of up to 3 or 4 ft and still provide a significant range (over a mile in the demonstration hardware in fresh water).
- Attenuation of transmitted signals depends upon submergence depth and that salt water attenuation is particularly severe (compared to fresh water).
- The power required to break the water to air interface is frequency dependent (i.e., lower frequency gives more range for the same power).
- The efficiency of the loop antenna built into the transmitter decreases as the frequency decreases - an unfortunate fact.
- The range of the transmitter is somewhat affected by the orientation of the transmitter loop antenna in reference to the receiver antenna (i.e., whether the transmitter loop is 90°, 180°, 270°, or 360° turned from the receiver).

The life (duration of power source) test shows that the transmitter will continue to operate (although with decreased output) for about 48 hours with a 9 volt battery. The use of a ni-cad battery would keep the output at a higher level for a longer time with increased power.

Several problems warrant mention at this time. Distress frequencies (121.5 mHz) are not really required for transmission here, although they might have some advantage for shipboard monitoring. However, a man overboard transmitter (especially on

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the Great Lakes) probably need transmit for only a relatively short time, and monitoring from any distance is unlikely. Recall that the victim will require recovery in a short length of time. Any additional vessels other than ones in the immediate vicinity of the loss could not be effectively used in the search. There is a need for an examination of the radio frequency to be used in the MOS.

Another problem which must be solved is the actuation mechanism to activate the transmitter. Dayton (Reference 4) also did a brief investigation of automatic actuators. None of the types reported are appropriate for the MOS due to size or mode of operation. It is apparent that the actuation of the MOS transmitter must be made an integral part of the transmitter. There are some feasible ideas which might be incorporated after some additional research. Some of the possibilities were presented in Section 2.2.1 and 2.2.2.

The availability and selection of the appropriate shipborne equipment present an additional problem. It is apparent that the type of equipment will be dependent upon the type of MOS to be employed. Appendix B presents some yet-to-be resolved concepts including some ideas which consider operational requirements on merchantmen in the real world.

4.2 A Feasible MOS Concept

The system consists of a transmitter which transmits a pulsed continuous wave (CW) signal on contact with water. Each crewman will carry one of these transmitters while on deck or working on the dock. The system has complete accident area coverage because it triggers the alarm when the victim falls in the water. The location of the accident does not matter as long as it occurs within the range of the receiver. Ship modifications are minimal, consisting of a receiver unit, receiving antenna, and alarms mounted on the bridge and in the engine room. No interference is anticipated with the ship's operation. Ideally, the level of maintenance requirements will be a function of the shelf life of the batteries. The system has direction finding capabilities for quickly locating the victim in the water. A direction finder can be mounted on the ship and/or hand-carried for search operations from a life boat.

The main drawback is that the man must carry the transmitter on his person. At the very least this is an inconvenience to the crewman, and at the worst a disturbing encumberance depending on the weight and size of the device. The best unit would be as small and light in weight as possible and still have an effective transmitting range.

Based on some preliminary testing, the effects of RF shadowing caused by the ship itself when the victim is close alongside does not appear to be significant at this time. This was previously thought to be a problem.

The detection and location modes of the transmitter invite additional discussion in the context of a potential man overboard situation. If the scenario of events in a potential man overboard situation while underway are examined using the MOS, one can easily envision that the man-worn transmitter can activate a ship borne alarm, including visual/audible bridge and engine room indicators. This RF system receiver could be set up to recognize only the pulse code pattern and frequency of an activated man-worn transmitter. The receiver might even identify a particular crewman overboard by the pulse code pattern (each crewman would have a different pulse code pattern). Upon recognition of the pattern, the alarm would automatically be sounded. The officer on the bridge then sounds the "general quarters" alarm for the ship. This action would complete the "detection mode."

The system employed for location is a version of an ADF* system such as that used in aircraft. The ADF system is directionally sensitive and electronically "points" to the RF source. The ADF indicator provides a visual display (dial) that includes a needle which always points toward the radio source to which the receiver is tuned. The requirements of the MOS use the same principle but would require a less complex version of the usual ADF system. In the MOS the receiver would be tuned by the use of a crystal of the same frequency as the crystal in the transmitters so that no tuning effort would be required during the search. The unit would be portable and would be kept on the bridge. One additional feature not previously discussed is that the total detection and location sytem may include another transmitter other than the man-worn one. This transmitter would be launched remotely from the bridge with a ring buoy or self-inflating raft by a crewman. Thus the receiver may have more than one crystal or channel. The design of this second transmitter could be similar to the ELT/ERPIB switch now in use.

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* Automatic Direction Finder

The second transmitter could provide a <u>much</u> stronger signal for homing to the vicinity of the man overboard <u>and</u> provides a backup in event the man-worn transmitter fails. This may have particular value for salt water adaptation of the MOS. A life raft deployed at the same time would offer more visibility from the ship than the mere head of a man, and if the victim could board the raft it would greatly facilitate live rescue. If the ship were moored at a dock when the man went overboard, the crew should be able to visually locate the victim in the day. At night, location would be possible using lights.

A more complicated version of a shipboard receiving unit is conceivable that would indicate where on the ship the man fell overboard. It would be particularly useful when the ship was moored or at a dock. This system would include multiple antenna - at least one forward and one aft and/or one port and one starboard. This would determine differences in signal strength among the antenna locations and serve as an indicator of <u>where</u> the man is overboard. However, this requirement would probably complicate the reliability, maintenance, and use of the detection equipment beyond need.

4.3 Recommendations

Based upon the findings and conclusions of the work documented herein, it is recommended that the following action be undertaken. These recommendations would be incorporated into Phase II of a comprehensive approach to the man overboard project (see Section 1.1 for Phase definition). The recommendations are presented in three basic areas:

1) additional research requirements for the man overboard system
2) evaluation/selection of a MOS and fabrication/procurement of prototypes, and
3) testing/evaluation and MOS documentation of prototype MOS.

Item requirements for each of the areas include (but are not limited to) those listed in the section below.

Additional Research Requirements/Items

- Research and coordinate available radio frequencies (FCC and other sources)
- Research antenna size vs. frequency; research alternative antenna possibilities to increase performance with small loop size, and research antenna alternatives for lower transmitting frequency
- Evaluate using 121.5 and power requirements to operate in fresh water; assess range capability
- Research ADF for selected transmitter frequency
- Research automatic alarm makeup with radio signal as the initiator
- Research MOS transmitter activation device(s); methods for activating the MOS transmitter in the man overboard situation
- Research and evaluate power supply (battery) capabilities and select the best for power and life requirements of MOS
- Research pulse code and pulse decoder for "non-alarm" for other than man overboard situations
- Evaluate ship bridge layouts, antenna locations possible, etc.
- Coordinate, visit, interview ship owners and/or operators, relevant labor unions and insurance companies to determine requirements, preferences, attitudes, etc. toward MOS

Evaluation/Selection of a MOS and Fabrication/Procurement of Prototypes

- Select "best" frequency and activation method and fabricate MOS transmitters suitable for use in fresh water environment
- Select "best" frequency and activation method and fabricate MOS transmitters suitable for use in salt water environment
- Select methodology and fabricate shipboard detection and alarm system
- Select and procure ADF equipment suitable for MOS use

Testing/Evaluation and Documentation of Prototype MOS

- "Laboratory" test full up system including environmental testing - temperature, humidity, shock, vibration, etc.
- "Field test" equipment (MOS transmitter and receiver) in open water for demonstration purposes

- Prepare recommendations for undertaking Phase III of the man overboard project. These recommendations will include:
  - listing of specifications and documentation of the required hardware for an operational MOS
  - fabrication of several complete MOSs
  - conduct of field testing aboard ship for demonstration purposes and for preparation of final procedures
  - determination of purposed training procedures for crewmen
  - preparation of operational and maintenance manual(s)
  - six month usage by Merchant Marine personnel with feed-back of response from relevant crewmen
  - final evaluation of MOS after removal from vessel
  - Phase III final report.

For planning purposes, it may be estimated that the Phase II effort above would require 18-20 months including field work. A 2-man year effort is envisioned to accomplish the work. A likely material budget in the $15,000 to $25,000 range is anticipated depending upon the actual amount and type of hardware to be purchased.

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3. Keatinge, W. R., "Survival in Cold Water." Oxford: Blockwell Scientific Publications, 1969.

4. Dayton, Robert B., "Design Criteria For Advanced PFD's." Final Report. Operations Research, Incorporated for the U. S. Coast Guard. August 1974. NTIS No. AD-A010-404.

5. Stapleton, Sid, "The Facts of Life About EPIRBs." <u>Motor Boating and Sailing</u>. July, 1976. p. 44.

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APPENDIX A - MAN OVERBOARD SYSTEM (MOS) TRANSMITTER TESTS AND RESULTS

1.0 INTRODUCTION

In order to evaluate the feasibility of using the man-carried transmitter, a series of tests were conducted in both fresh water and salt water. Three transmitters were tested to determine relative performance characteristics of each of the three frequencies under consideration.

Transmitter #1 - 14.950 mHz
Transmitter #2 - 26.760 mHz
Transmitter #3 - 37.600 mHz

The testing of different frequencies was intended to provide an indication of the signal range obtainable from higher and lower frequencies. A full wave dipole antenna was selected for each of the transmitter frequencies to match the receiver to the transmitter.

The tests conducted are discussed in appended Sections 2.1, 2.2, and 2.3 along with tabulated and graphical data. Section 2.4 summarizes the results.

2.0 TESTS PERFORMED

The testing was conducted in two water environments: fresh water and salt water.

2.1 Fresh Water Tests

TEST #1 - Using a single frequency Johnson (CB) receiver with a 26.760 mHz crystal, a range test was conducted for water submergence and transmitter loop antenna orientation variables. This test was made with a full wave dipole antenna setup as shown in Figure 1. All tests in this series were conducted using the 26.760 mHz transmitter. The transmitter was mounted to a wooden pole which had depth and orientation markings as shown in Figure 2. Air temperature was 78°F and water temperature was 66°F. The range of the transmitter was tested at distances of 1150 ft, 2000 ft, and 6000 ft from the receiver antenna. Setup for the testing was accomplished using a small fiberglas boat.

Data was acquired at each distance with the transmitter in two depth conditions: just below the water surface, and 3 ft below the water surface. At each depth, the transmitter was rotated to different antenna orientation positions. The positions included 0°, 45°, 90°, 180°, 225°, 270°, 315°, and 360°.

The data from these tests are shown in Table 1 and in Figure 3. The range data for the 6000 ft distance was tabulated only for various depths and not for antenna orientation. This data is shown in Figure 4.

TEST #2 - Test 2 was conducted to obtain relative signal strength for each of the three transmitters. Matched dipole antennas were set up and signal strength was obtained using a HP 8557A spectrum analyzer. The test setup was as shown in Figure 5. One of the investigators attached the transmitter to his leg and was positioned 33 ft from the antenna. Data was acquired for the various transmitter loop orientations. This data is shown in Table 2 and is presented graphically in Figure 6.

TEST #3 - This test was conducted in order to obtain signal strength, as a function of depth of immersion. Data was recorded using the HP 8557A spectrum analyzer. Each of the three transmitters was in turn submerged directly below the analyzer and data recorded at various depths up to 8.5 ft. The data acquired is shown in Table 3 and Figure 7.

It was noted that there was a general tendency for signal strength to rise at the four (4) ft depth of immersion. This may have been caused by ground reflections in the water, which was comparatively shallow (i.e., nine ft). The depth of immersion test was repeated in ninety ft water in order to minimize the possible effects of ground relection. The results of this are shown in Table 4 and Figure 8.

An overall summary of the fresh water tests is presented graphically in Figure 10.

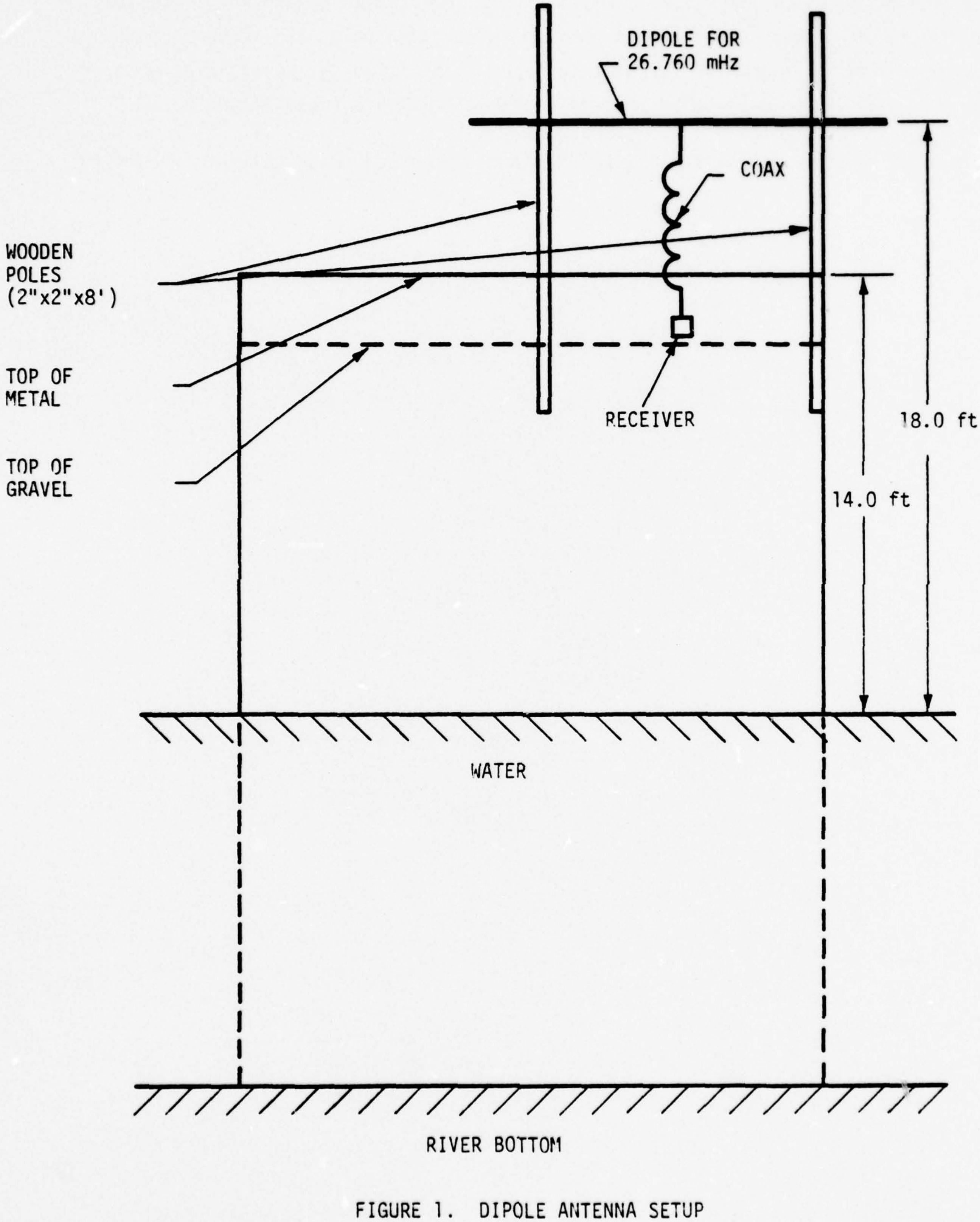

FIGURE 1. DIPOLE ANTENNA SETUP

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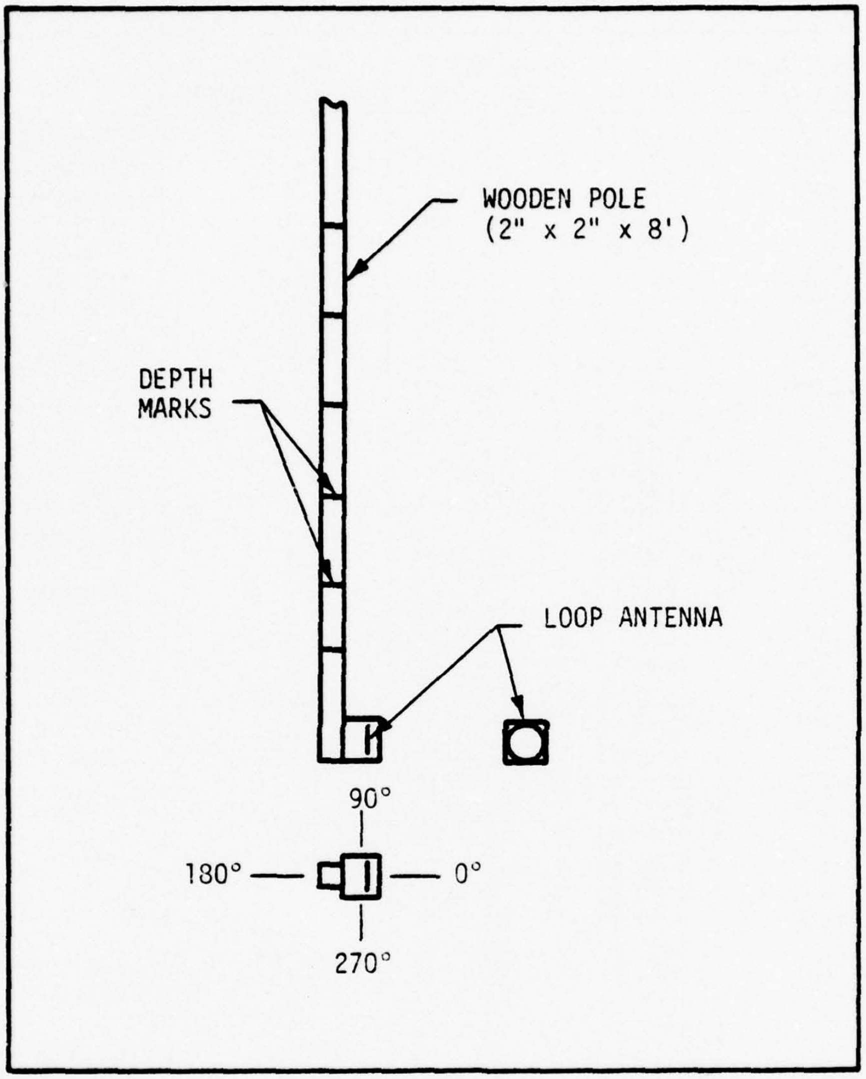

FIGURE 2. SETUP SHOWING DEPTH AND ORIENTATION MARKINGS

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TABLE 1. RESULTS OF TEST 1: LOOP RECEIVER ANTENNA ORIENTATION VS WATER SUBMERGENCE VS RANGE

DEPTH OF TRANSMITTER	POSITION OF LOOP ANT.	RANGE	HEIGHT OF REC. ANT.	RELATIVE SIG. STRENGTH	REMARKS
Just	0°	1152 ft	18.0 ft	3	There was no field
Under	90°	1152 ft	18.0 ft	4	strength meter on
the	180°	1152 ft	18.0 ft	3	this receiver; there-
Surface	270°	1152 ft	18.0 ft	4	fore, all signals were
	45°	1152 ft	18.0 ft	5	compared to the first
	315°	1152 ft	18.0 ft	3.5	reading, and given a
	225°	1152 ft	18.0 ft	3.5	relative value between
3 ft	0°	1152 ft	18.0 ft	2	1 and 5 with the
(0.9 m)	90°	1152 ft	18.0 ft	1.5	values normalized for
Below	180°	1152 ft	18.0 ft	1.5	the first reading
the	270°	1152 ft	18.0 ft	1.5	equal to 3.
Surface	45°	1152 ft	18.0 ft	1.7	(1) Quite weak signal
	315°	1152 ft	18.0 ft	1 (1)	barely audible above
	225°	1152 ft	18.0 ft	1.7	wind noise (wind vel.
					10-15 knots.
Just	0°	2000 ft	18.0 ft	3	R.F. gain was adjusted
Under	45°	2000 ft	18.0 ft	4	to allow the first
the	90°	2000 ft	18.0 ft	4	signal here to be
Surface	135°	2000 ft	18.0 ft	4	barely audible. Varia-
	180°	2000 ft	18.0 ft	2	tions here are equivalent
	225°	2000 ft	18.0 ft	3.5	to those above. First
	270°	2000 ft	18.0 ft	5	reading given an arbi-
	315°	2000 ft	18.0 ft	5	trary reading of 5.
	360°	2000 ft	18.0 ft	3	
3 ft	0°	2000 ft	18.0 ft	3	
(0.9 m)	45°	2000 ft	18.0 ft	4	
Below	90°	2000 ft	18.0 ft	5	
the	135°	2000 ft	18.0 ft	5	
Surface	180°	2000 ft	18.0 ft	4.5	
	225°	2000 ft	18.0 ft	4.5	
	270°	2000 ft	18.0 ft	4	
	315°	2000 ft	18.0 ft	4	
	0°	2000 ft	18.0 ft	3	
Just	90°	1.125 mi.	18.0 ft	3	Reset R.F. gain to
Under	0°	1.125 mi.	18.0 ft	2.5	barely audible level as
the	45°	1.125 mi.	18.0 ft	2.5	before relative differ-
Surface	90°	1.125 mi.	18.0 ft	3	ences are equivalent to
	135°	1.125 mi.	18.0 ft	2.5	all previous readings.
	180°	1.125 mi.	18.0 ft	2.5	(1) Intermittant beep
	225°	1.125 mi.	18.0 ft	3	detection.
	270°	1.125 mi.	18.0 ft	3.5	(2) Raised antenna by
	315°	1.125 mi.	18.0 ft	3	6 ft., increase scan
	0°	1.125 mi.	18.0 ft	2.5 (1)	reliability.
	0°	1.125 mi.	24.0 ft	3.0 (2)	

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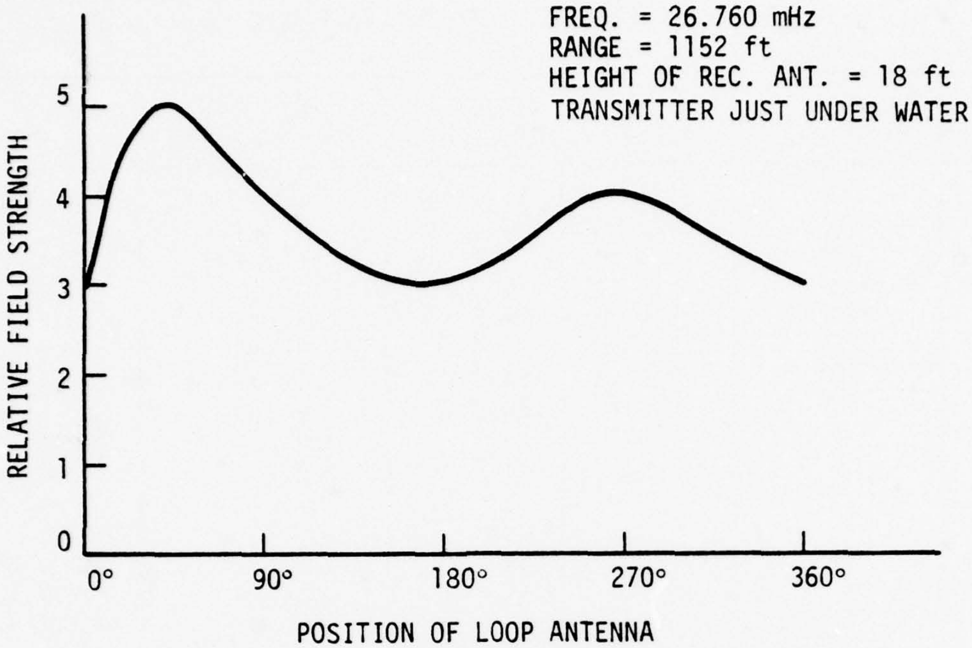
TABLE I. RESULTS OF TEST I: LOOP RECEIVER ANTENNA ORIENTATION VS WATER SUBMERGENCE VS RANGE, Concluded

DEPTH OF TRANSMITTER	POSITION OF LOOP ANT.	RANGE	HEIGHT OF REC. ANT.	RELATIVE SIG. STRENGTH	REMARKS
3 ft (0.9 m) Below the Surface	90°	1.125 mi.	24.0 ft	3	
	135°	1.125 mi.	24.0 ft	2.5 (3)	(3) Intermittant detection, but covered with a lot of C.B. noise
	180°	1.125 mi.	24.0 ft	0.5 (4)	(4) Cannot detect definite signal
	225°	1.125 mi.	24.0 ft	1	
	270°	1.125 mi.	24.0 ft	1.5	
	315°	1.125 mi.	24.0 ft	1 (5)	(5) Distinguishable above C.B. traffic
	0°	1.125 mi.	24.0 ft	No Trace	
3 ft Above the Surface	90°	1.125 mi.	24.0 ft	2 (6)	(6) Intermittant but readable signal is as expected since loop is tapped for water imped. match.
Just Below the Surface	90°	1.125 mi.	24.0 ft	3 (1)	(1) Dipole ant. was moved to vertically polarize
	0°	1.125 mi.	24.0 ft	2	
3 ft Below	90°	1.125 mi.	24.0 ft	2.5	
8 ft Below	90°	1.125 mi.	24.0 ft	1.5	
3 ft Below	0°	1.125 mi.	24.0 ft	1	



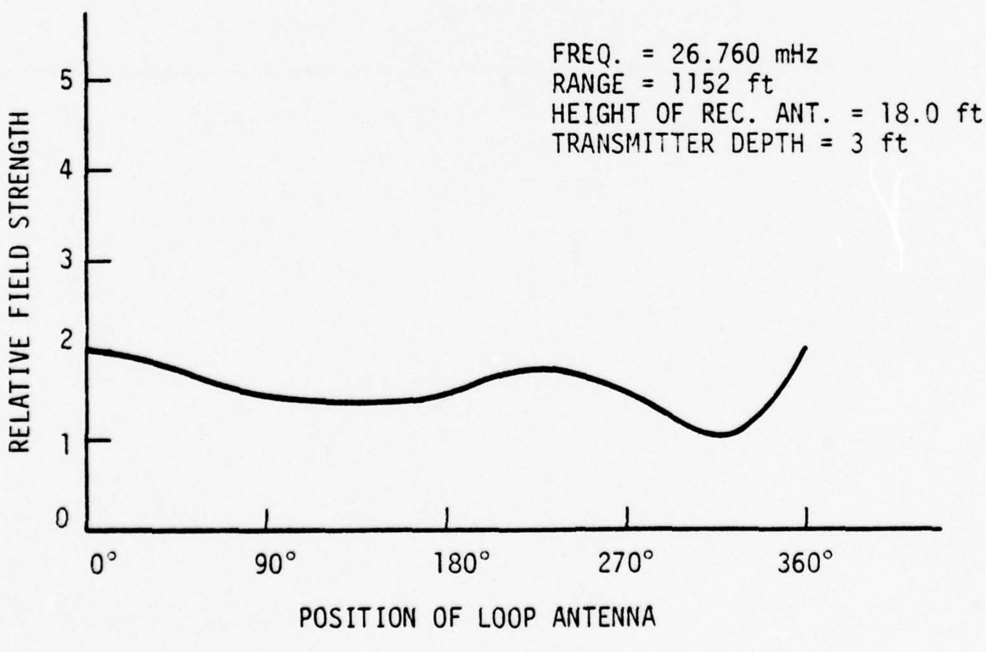
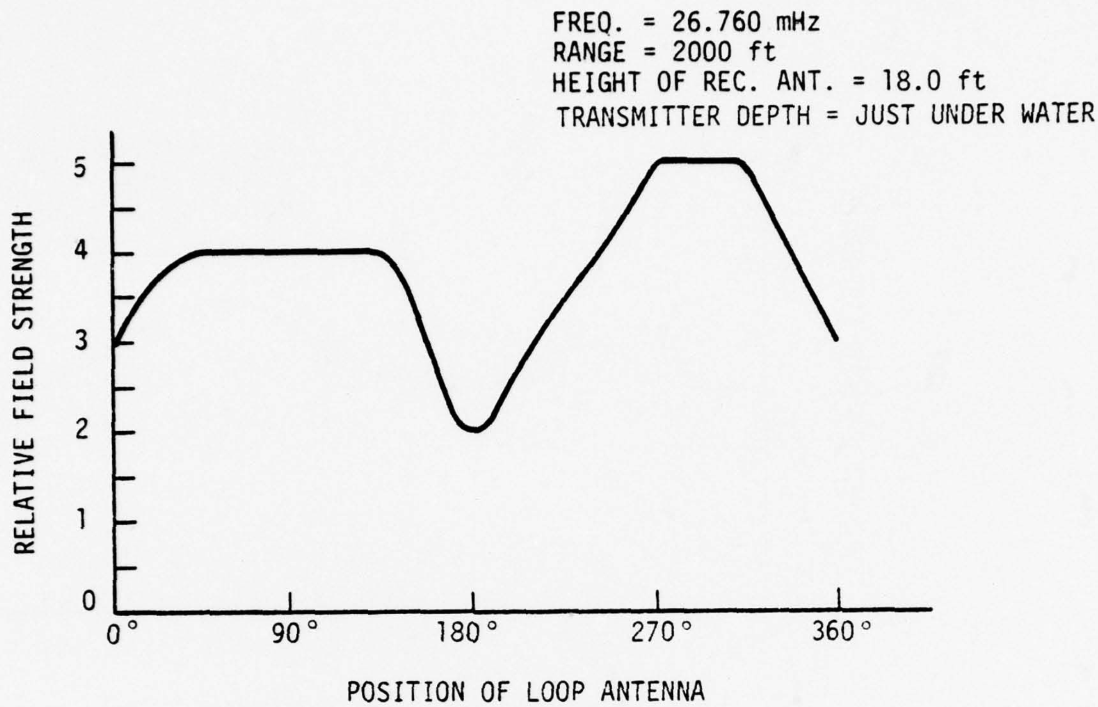


FIGURE 3. RESULTS OF TEST 1: LOOP RECEIVER ANTENNA ORIENTATION VS WATER SUBMERGENCE VS RANGE



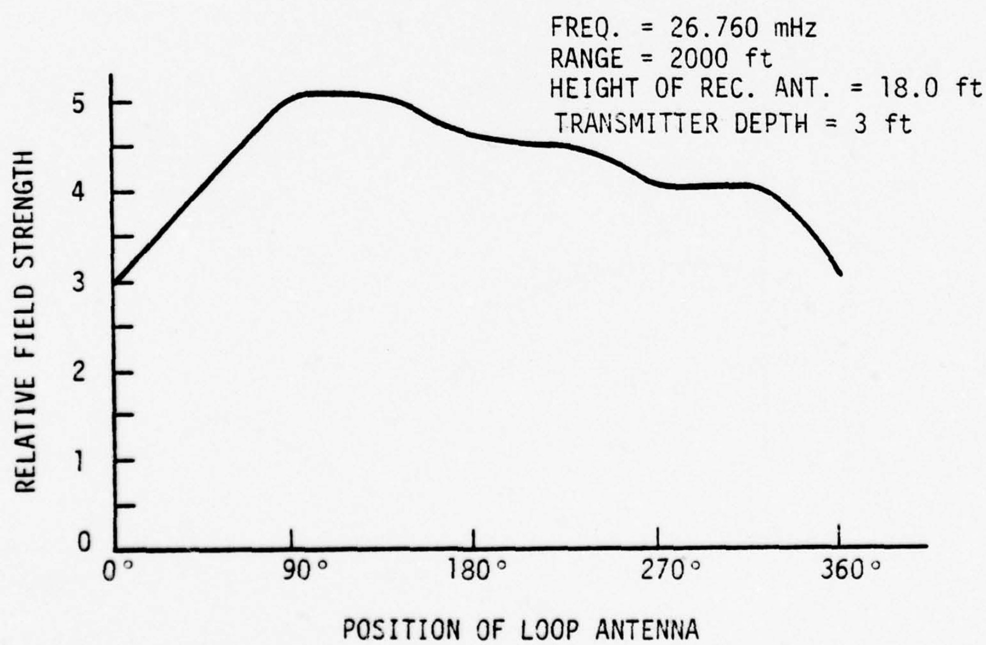
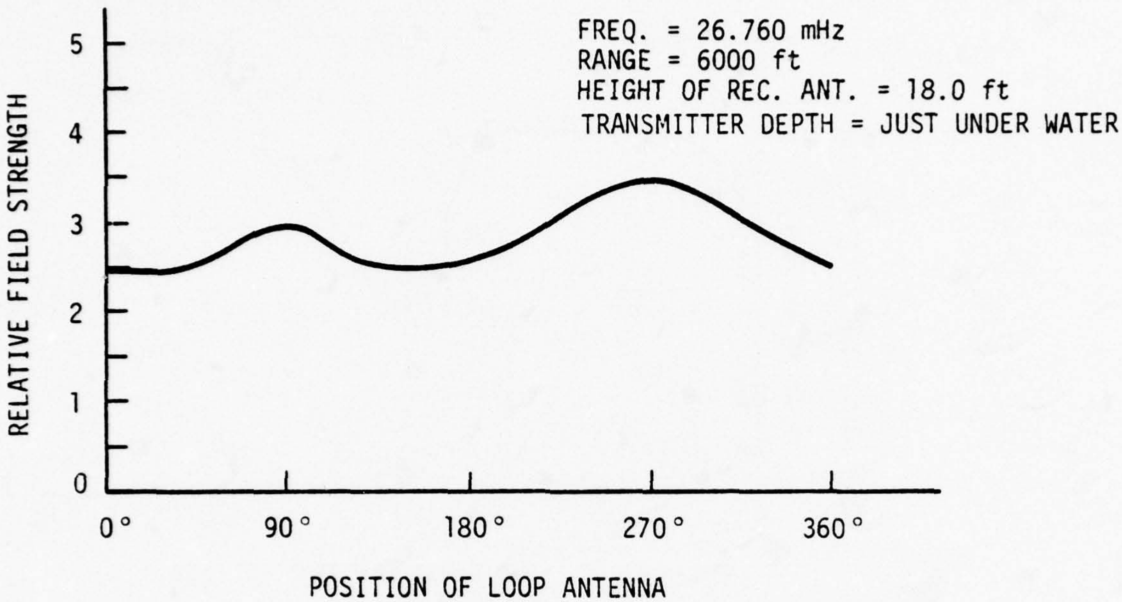


FIGURE 3. RESULTS OF TEST 1: LOOP RECEIVER ANTENNA ORIENTATION VS WATER SUBMERGENCE VS RANGE, Continued



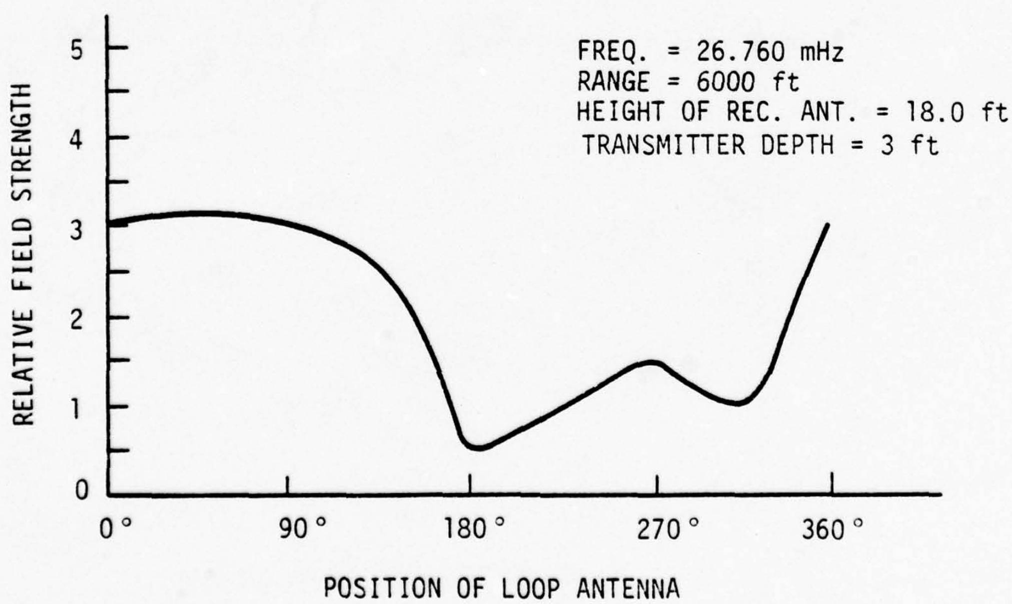


FIGURE 3. RESULTS OF TEST 1: LOOP RECEIVER ANTENNA ORIENTATION VS WATER SUBMERGENCE VS RANGE, Concluded

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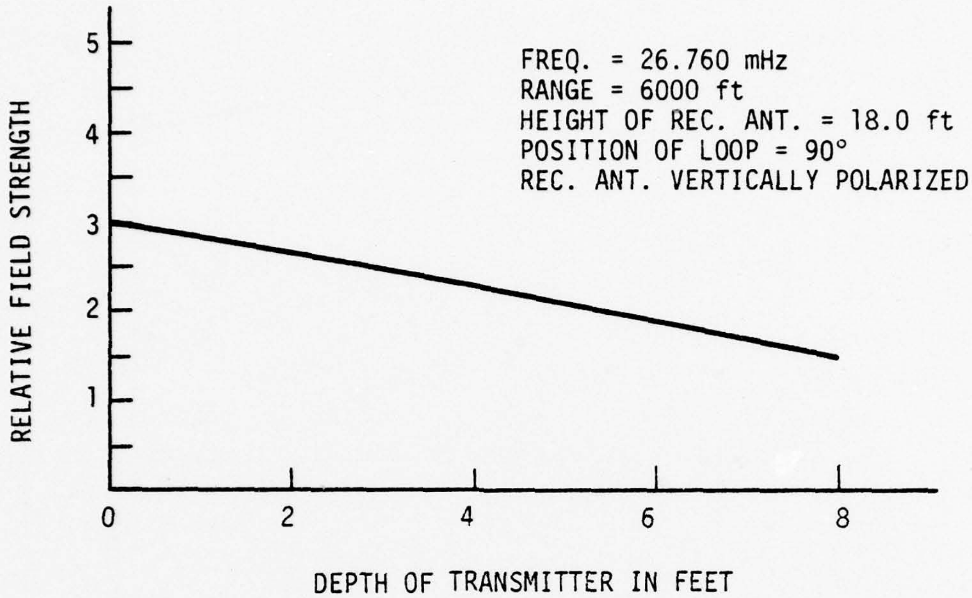

FIGURE 4. RESULTS OF TEST 1: SIGNAL STRENGTH VS DEPTH

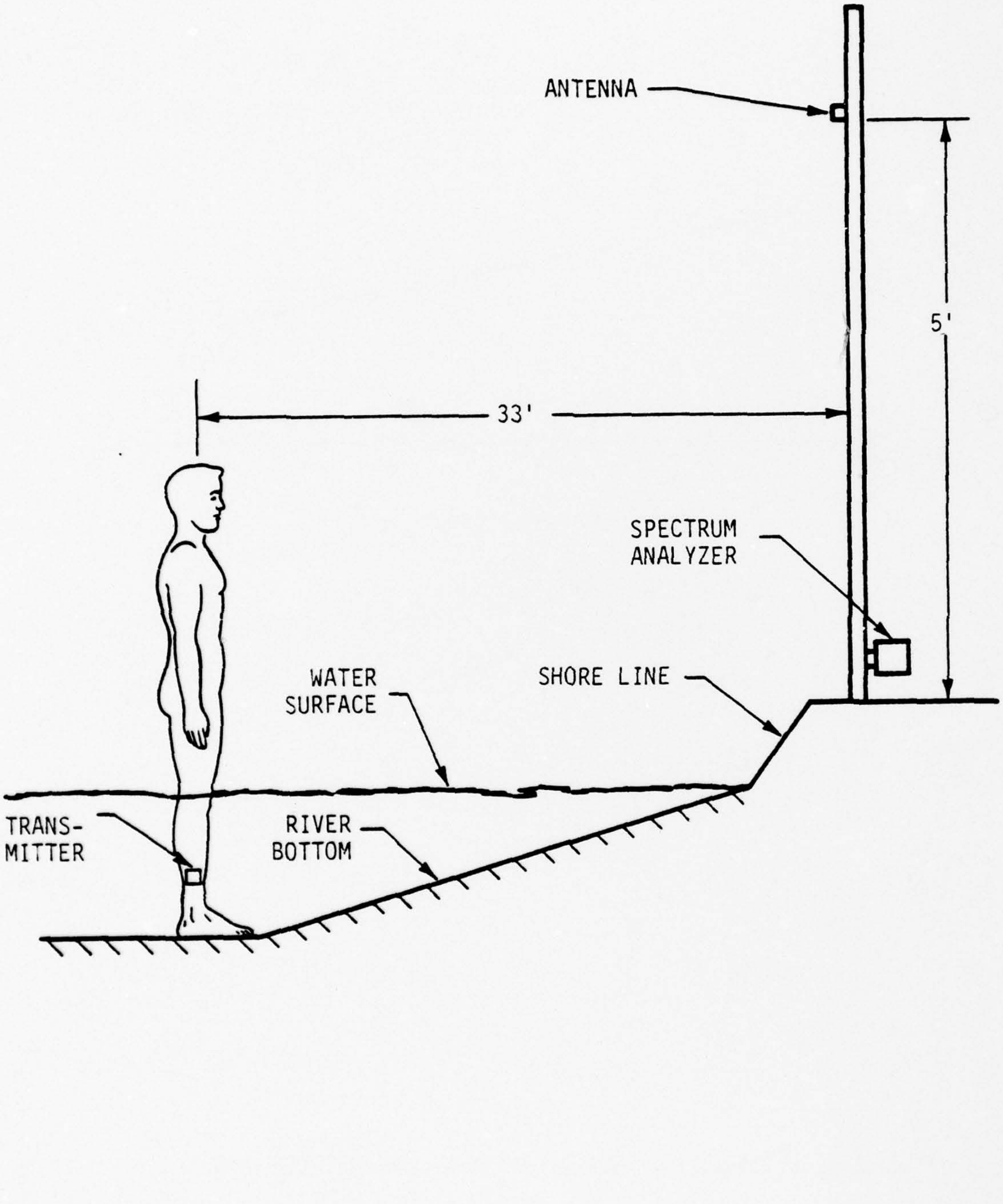

FIGURE 5. TEST SETUP FOR TEST 2

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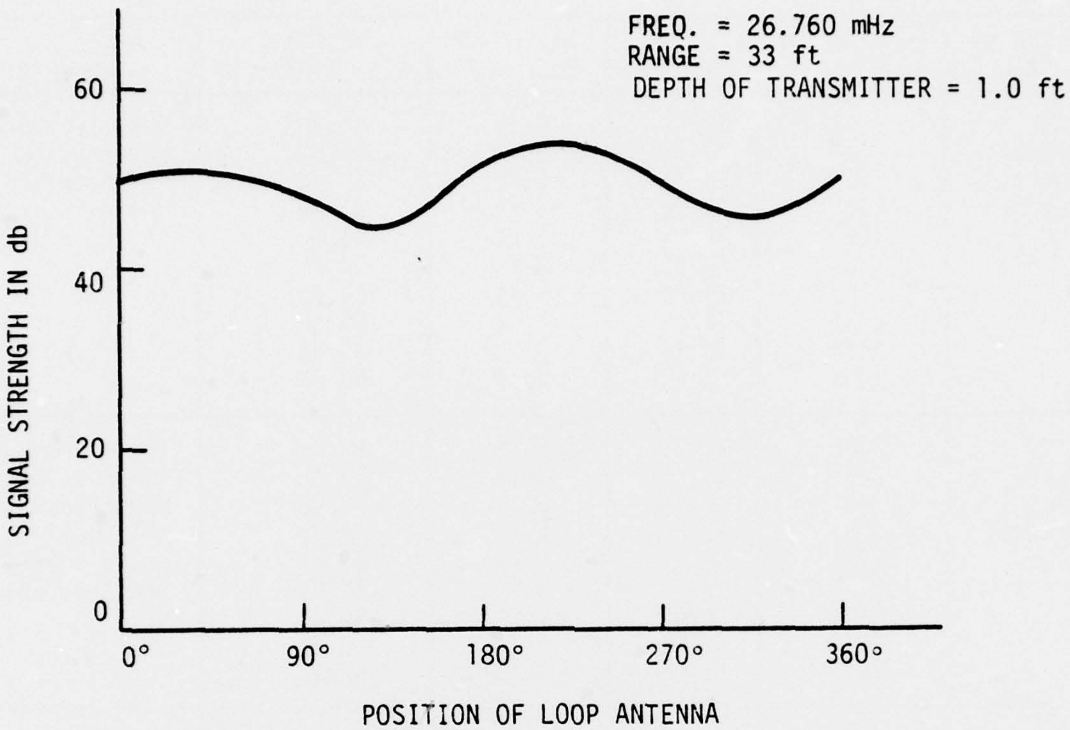
TABLE 2. RESULTS OF TEST 2: SIGNAL STRENGTH VS RELATIVE TRANSMITTER LOOP ORIENTATIONS

DEPTH OF TRANSMITTER	POSITION OF LOOP ANT.	RANGE	HEIGHT OF REC. ANT.	RELATIVE SIG. STRENGTH	REMARKS
1 ft	90°	33 ft	5 ft	50 db	These measurements were
Below	0°	33 ft	5 ft	50 db	taken using the dipole
the	45°	33 ft	5 ft	51 db	cut for the 14 MHz
Surface	90°	33 ft	5 ft	47 db	signal but using the
	135°	33 ft	5 ft	46 db	26.760 MHz transmitter
	180°	33 ft	5 ft	52 db	
	225°	33 ft	5 ft	54 db	
	270°	33 ft	5 ft	50 db	
	315°	33 ft	5 ft	46 db	
	0°	33 ft	5 ft	50 db	
1 ft	0°	33 ft	5 ft	52 db	These measurements were
Below	45°	33 ft	5 ft	46 db	taken using the 14.950
the	90°	33 ft	5 ft	42 db	MHz transmitter with
Surface	135°	33 ft	5 ft	48 db	the receiving antenna
	180°	33 ft	5 ft	51 db	cross polarized with
	225°	33 ft	5 ft	49 db	the loop antenna.
	270°	33 ft	5 ft	44 db	
	315°	33 ft	5 ft	50 db	
	360°	33 ft	5 ft	52 db	
1 ft	0°	33 ft	5 ft	69 db	These measurements were
Below	45°	33 ft	5 ft	65 db	taken using the 26.760
the	90°	33 ft	5 ft	55 db	MHz transmitter with
Surface	135°	33 ft	5 ft	68 db	the dipole cut for the
	180°	33 ft	5 ft	70 db	right length.
	225°	33 ft	5 ft	68 db	
	270°	33 ft	5 ft	56 db	
	315°	33 ft	5 ft	65 db	
	360°	33 ft	5 ft	69 db	
1 ft	0°	33 ft	5 ft	40 db	These measurements taken
Below	45°	33 ft	5 ft	40 db	using the 37.600 MHz
the	90°	33 ft	5 ft	40 db	transmitter with the
Surface	135°	33 ft	5 ft	38 db	dipole cut for the
	180°	33 ft	5 ft	40 db	right length.
	225°	33 ft	5 ft	44 db	
	270°	33 ft	5 ft	46 db	
	315°	33 ft	5 ft	44 db	
	360°	33 ft	5 ft	40 db	



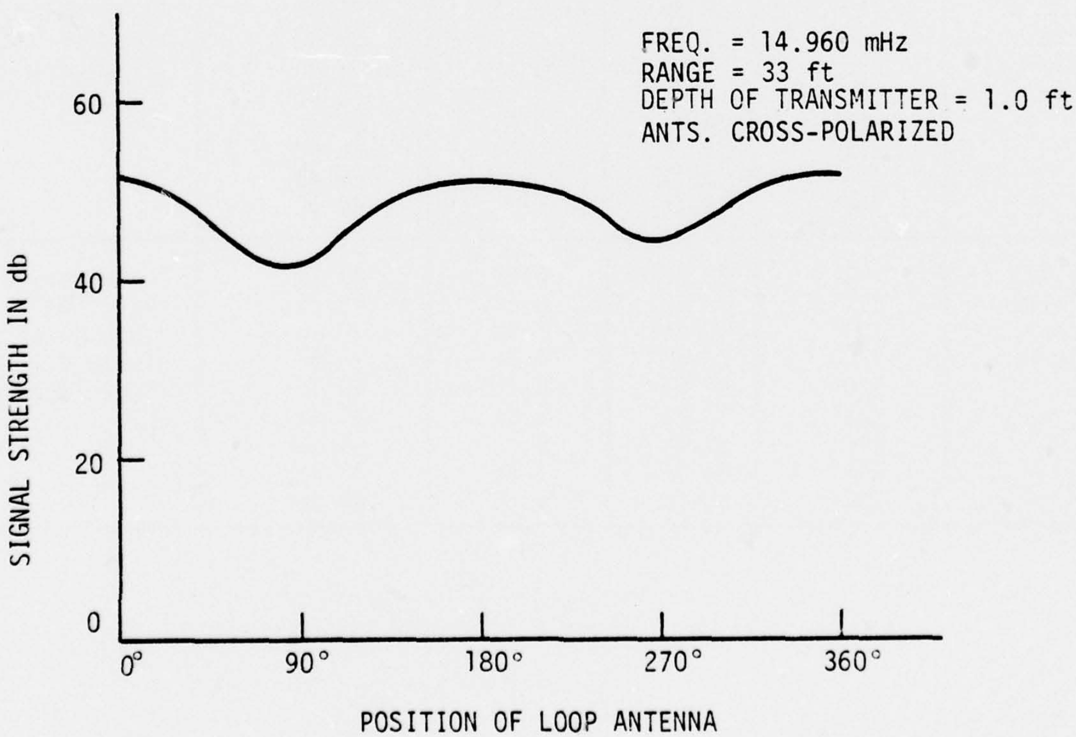


FIGURE 6. RESULTS OF TEST 2: SIGNAL STRENGTH VS RELATIVE TRANSMITTER LOOP ORIENTATIONS

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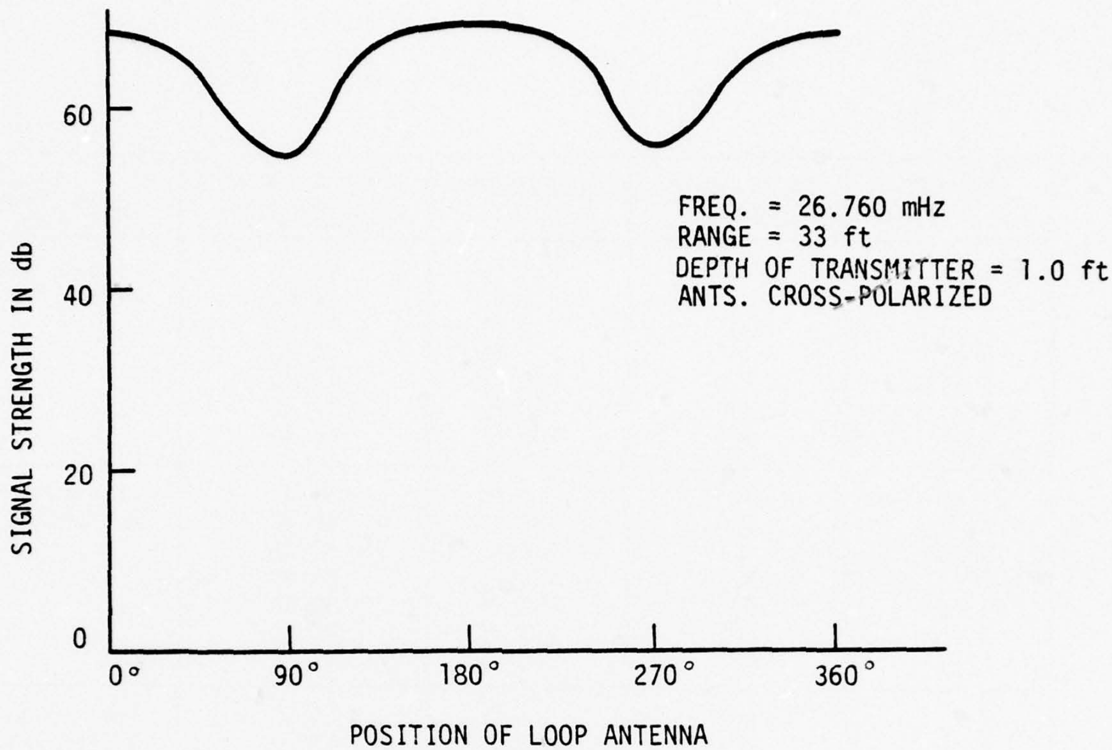

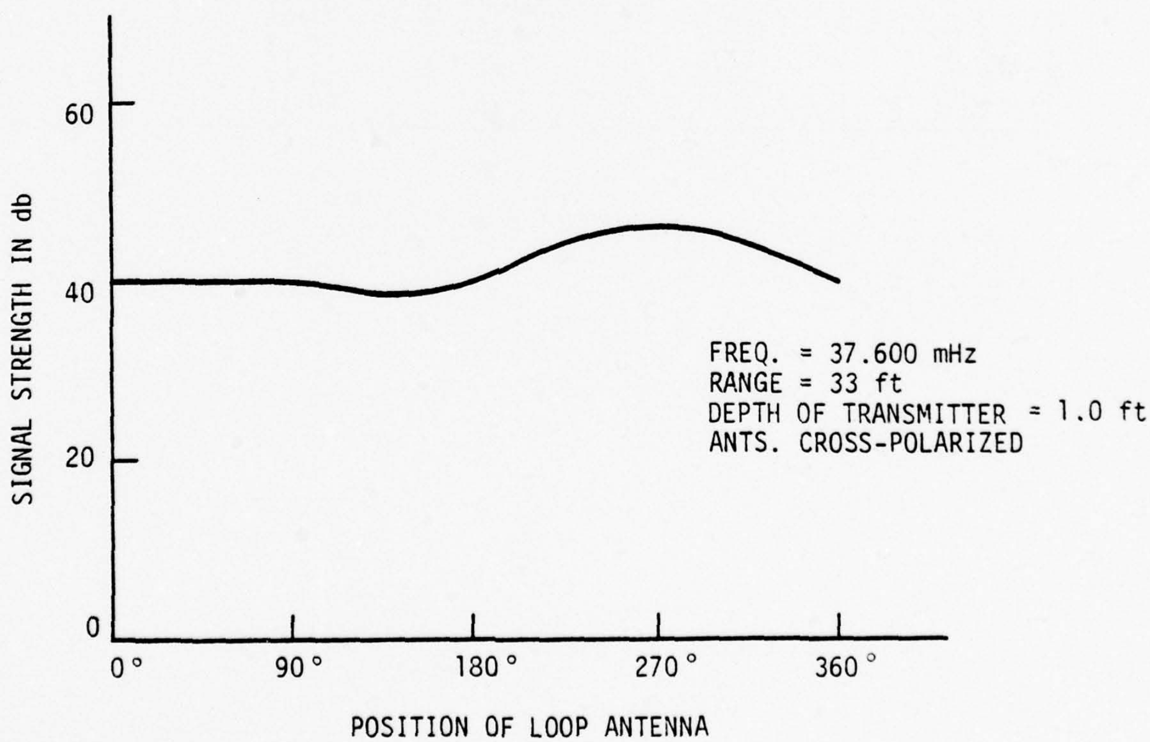

FIGURE 6. RESULTS OF TEST 2: SIGNAL STRENGTH VS RELATIVE TRANSMITTER LOOP ORIENTATIONS, Concluded

TABLE 3. RESULTS OF TEST 3: SIGNAL STRENGTH AS A FUNCTION OF DEPTH OF TRANSMITTER IMMERSION

DEPTH OF TRANSMITTER	POSITION OF LOOP ANT.	HEIGHT OF REC. ANT.	RELATIVE SIG. STRENGTH	REMARKS (WATER DEPTH 8 ft)
1 ft	90°	1.5 ft	46 db	Transmitter frequency 14.960 mHz
2 ft	90°	1.5 ft	43 db	
3 ft	90°	1.5 ft	41 db	
4 ft	90°	1.5 ft	44 db	
5 ft	90°	1.5 ft	44 db	
6 ft	90°	1.5 ft	42 db	
7 ft	90°	1.5 ft	40 db	
1 ft	90°	1.5 ft	64 db	Transmitter frequency 26.760 mHz
2 ft	90°	1.5 ft	60 db	
3 ft	90°	1.5 ft	55 db	
4 ft	90°	1.5 ft	44 db	
5 ft	90°	1.5 ft	50 db	
6 ft	90°	1.5 ft	56 db	
7 ft	90°	1.5 ft	51 db	
1 ft	90°	1.5 ft	58 db	Transmitter frequency 37.600 mHz
2 ft	90°	1.5 ft	54 db	
3 ft	90°	1.5 ft	48 db	
4 ft	90°	1.5 ft	54 db	
5 ft	90°	1.5 ft	56 db	
6 ft	90°	1.5 ft	56 db	
7 ft	90°	1.5 ft	50 db	

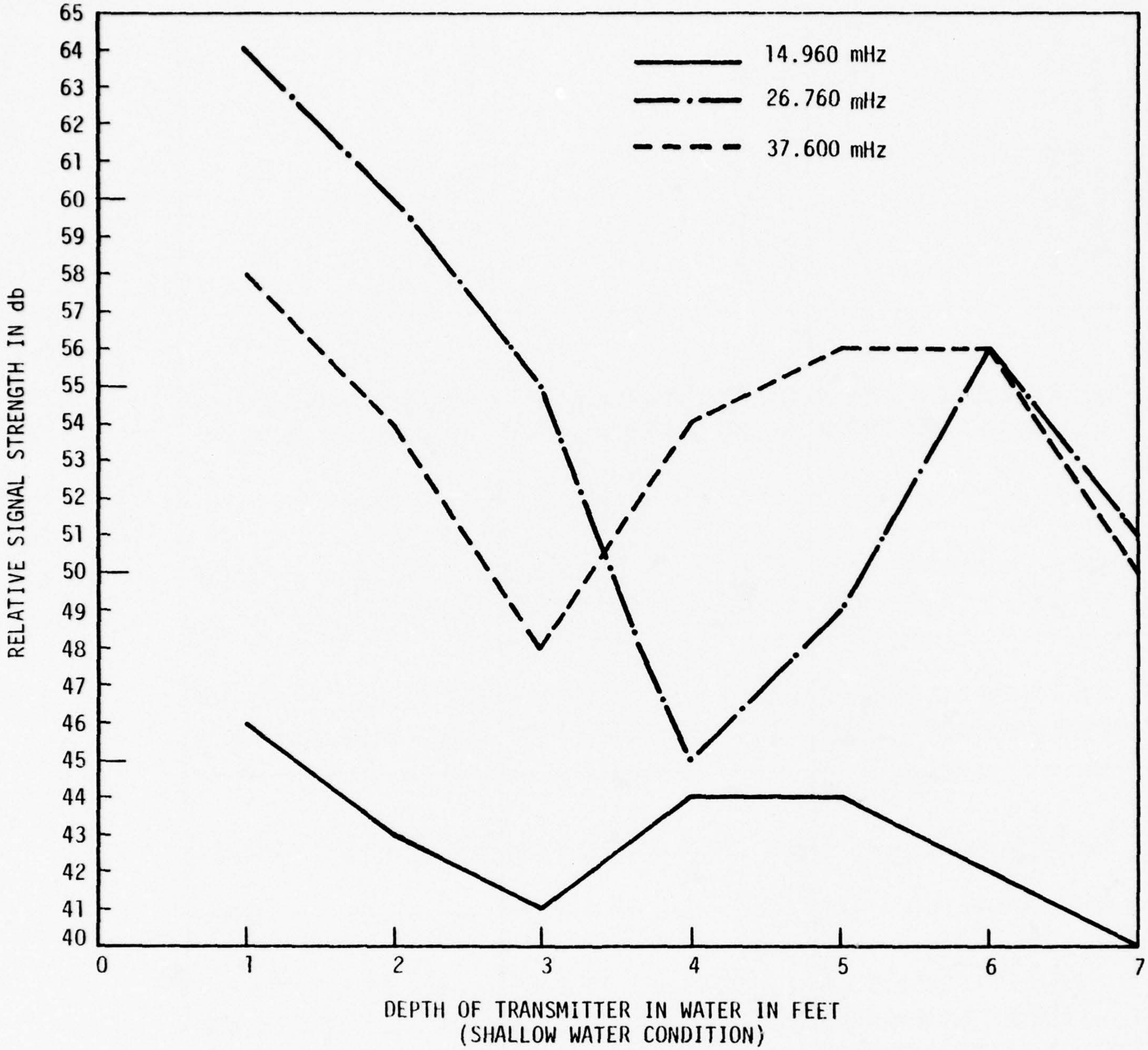

FIGURE 7. RESULTS OF TEST 3: SIGNAL STRENGTH AS A FUNCTION OF DEPTH OF TRANSMITTER IMMERSION

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TABLE 4. RESULTS OF TEST 3: SIGNAL STRENGTH VS DEPTH OF SUBMERSION IN 90 FT OF WATER

DEPTH OF TRANSMITTER	POSITION OF LOOP ANT.	RANGE	HEIGHT OF REC. ANT.	RELATIVE SIG. STRENGTH	REMARKS
1 in.	90°	19 in.	18 in.	42 db	Transmitter Frequency = 14.960 mHz Depth of water = 90 ft
6 in.	90°	24 in.	18 in.	41 db	
12 in.	90°	30 in.	18 in.	40 db	
18 in.	90°	36 in.	18 in.	38 db	
24 in.	90°	42 in.	18 in.	38 db	
30 in.	90°	48 in.	18 in.	38 db	
36 in.	90°	54 in.	18 in.	37 db	
42 in.	90°	60 in.	18 in.	36 db	
48 in.	90°	66 in.	18 in.	36 db	
54 in.	90°	72 in.	18 in.	35 db	
60 in.	90°	78 in.	18 in.	34 db	
66 in.	90°	84 in.	18 in.	32 db	
84 in.	90°	102 in.	18 in.	26 db	
1 in.	90°	19 in.	18 in.	68 db	Transmitter Frequency= 26.760 mHz Depth of water = 90 ft
6 in.	90°	24 in.	18 in.	67 db	
12 in.	90°	30 in.	18 in.	66 db	
18 in.	90°	36 in.	18 in.	65 db	
24 in.	90°	42 in.	18 in.	64 db	
30 in.	90°	48 in.	18 in.	63 db	
36 in.	90°	54 in.	18 in.	63 db	
42 in.	90°	60 in.	18 in.	62 db	
48 in.	90°	66 in.	18 in.	61 db	
54 in.	90°	72 in.	18 in.	60 db	
60 in.	90°	78 in.	18 in.	59 db	
66 in.	90°	84 in.	18 in.	58 db	
84 in.	90°	102 in.	18 in.	56 db	
1 in.	90°	19 in.	18 in.	58 db	Transmitter Frequency= 37.600 mHz Depth of water = 90 ft
6 in.	90°	24 in.	18 in.	58 db	
12 in.	90°	30 in.	18 in.	58 db	
18 in.	90°	36 in.	18 in.	58 db	
24 in.	90°	42 in.	18 in.	57 db	
30 in.	90°	48 in.	18 in.	56 db	
36 in.	90°	54 in.	18 in.	56 db	
42 in.	90°	60 in.	18 in.	55 db	
48 in.	90°	66 in.	18 in.	55 db	
54 in.	90°	72 in.	18 in.	54 db	
60 in.	90°	78 in.	18 in.	53 db	
66 in.	90°	84 in.	18 in.	53 db	
84 in.	90°	102 in.	18 in.	50 db	

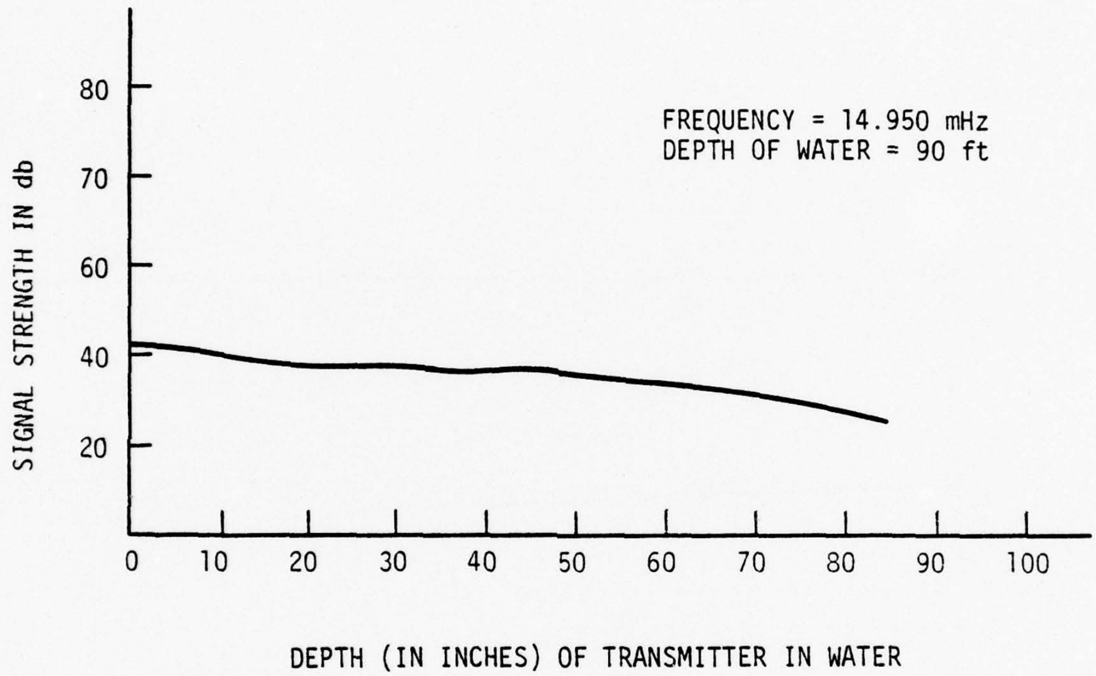
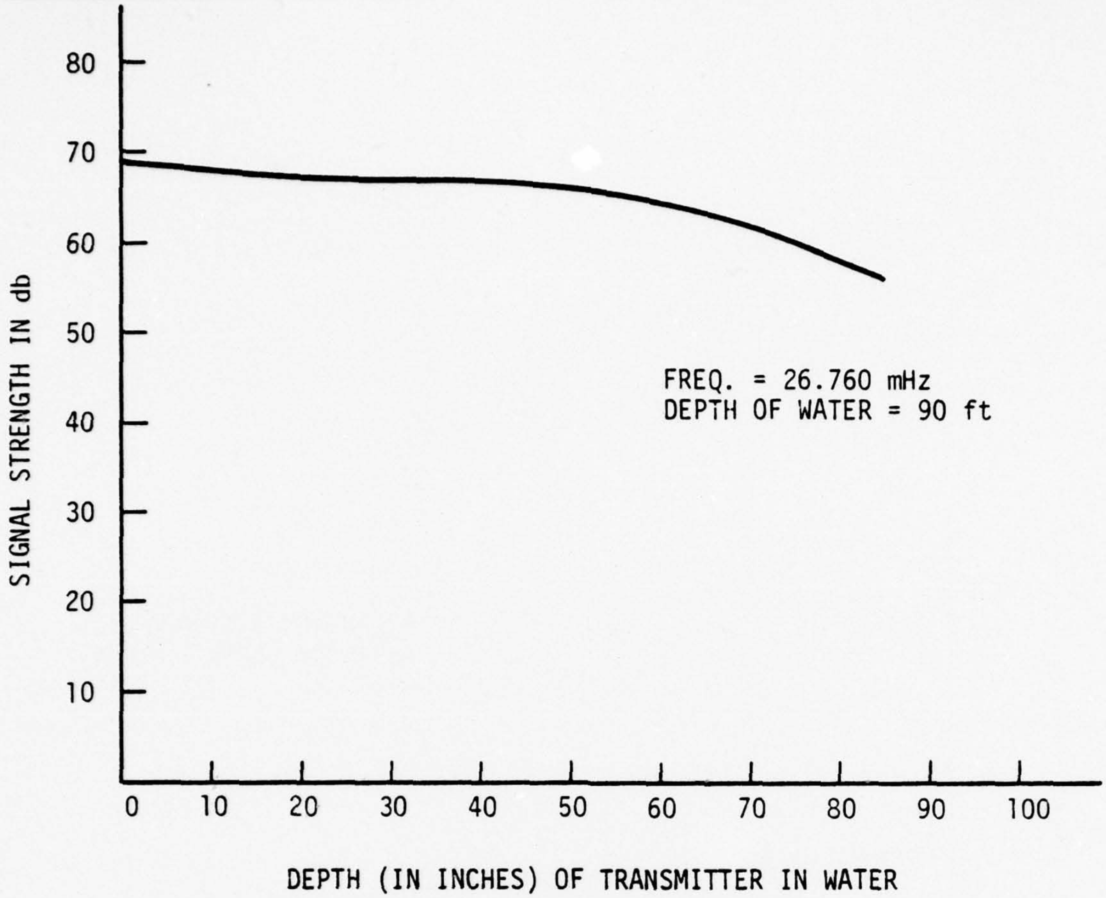


FIGURE 8. RESULTS OF TEST 3: SIGNAL STRENGTH VS DEPTH OF SUBMERSION IN 90 FT OF WATER



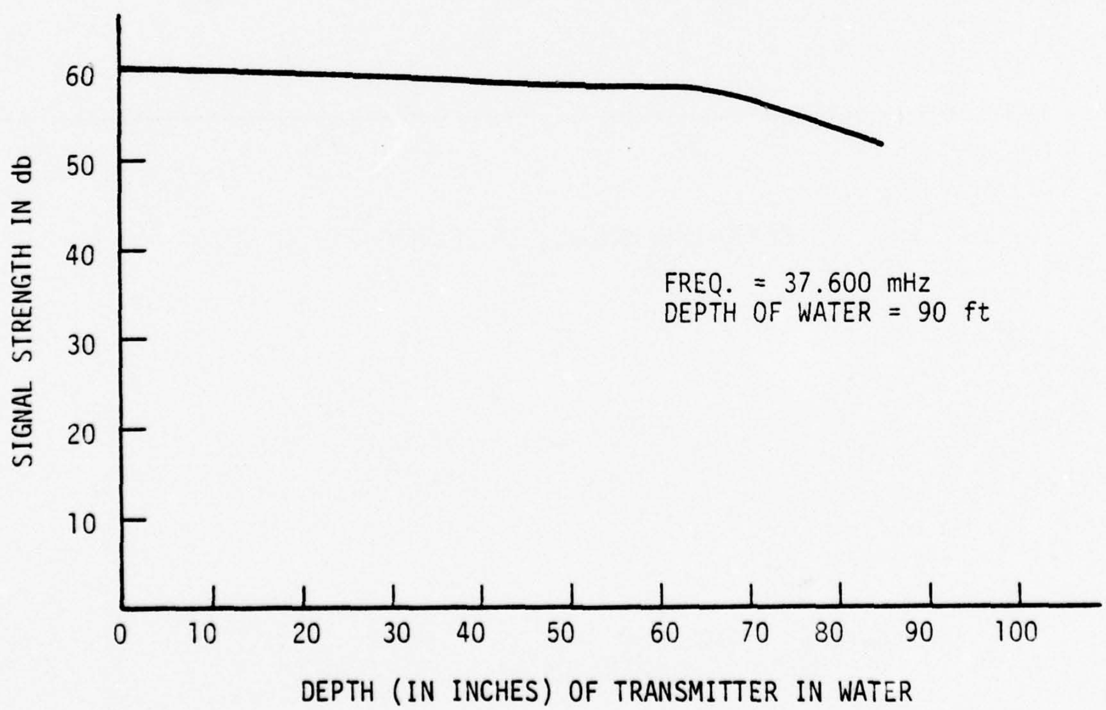


FIGURE 8. RESULTS OF TEST 3: SIGNAL STRENGTH VS DEPTH OF SUBMERSION IN 90 FT OF WATER, Concluded

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2.2 Salt Water Tests

Salt water tests of the transmitter were conducted to determine whether the predicted high attenuation of salt water did occur. The tests are described below.

TEST #1s - Test 1s was conducted to determine range of the transmitter signals at a limited submergence depth. The test was performed in the Gulf of Mexico (Panama City), air and water temperatures were 85°F and 75°F respectively. The distances for various ranges were measured using a radar set. The submergence depth required for the range tests was confined to only 6 in. to 12 in. There was a sudden and complete loss of signal at a 2 ft to 3 ft depth at a fairly close range.

The 26.760 mHz transmitter was taped to a wooden pole which was in turn taped to a wooden structure supporting a navigation aid. The pole was lowered into the sea water until the transmitter was 6 to 12 in. below the surface. The receiver and receiving antenna were then placed at varying distances from the transmitter and the relative signal strength recorded. The results were tabulated in graphic form for this discussion rather than in tables. Data was recorded using the spectrum analyzer. The results of Test 1s are shown in Figure 9.

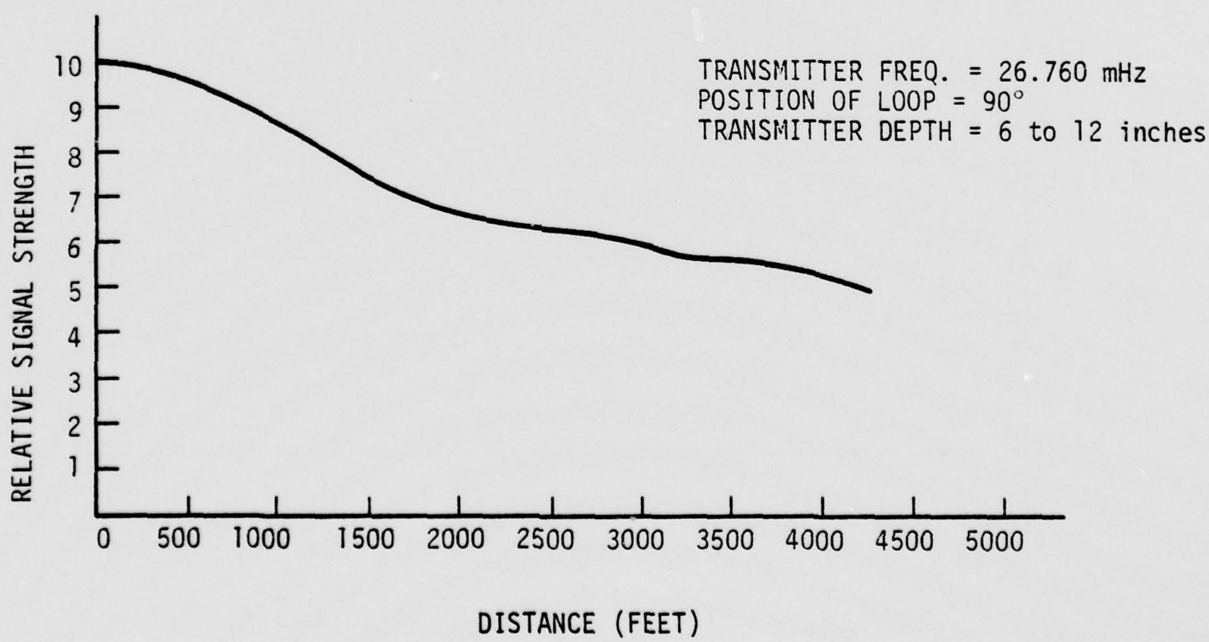


FIGURE 9. RESULTS OF TEST 1s: SIGNAL STRENGTH VS. RANGE AT LIMITED DEPTH

TEST #2s - Test 2s was conducted to obtain relative signal strength as a function of the three transmitting frequencies and depth of immersion. The water depth was 30 ft. Each of the transmitters were lowered in turn to varying depths and the signal strength recorded. The receiving antenna was positioned immediately above the transmitter. Data was recorded using the spectrum analyzer. Results are shown in Figure 10.

TEST #3s - For the final salt water test the 26.760 mHz transmitter was hand held by one of the investigators and submerged in salt water. The purpose was to determine if the person's head (being out of the water) would increase the antenna effect and reduce the attenuation from the salt water. The range and depth tests were the same as for Test 1s, and there was no change in results.

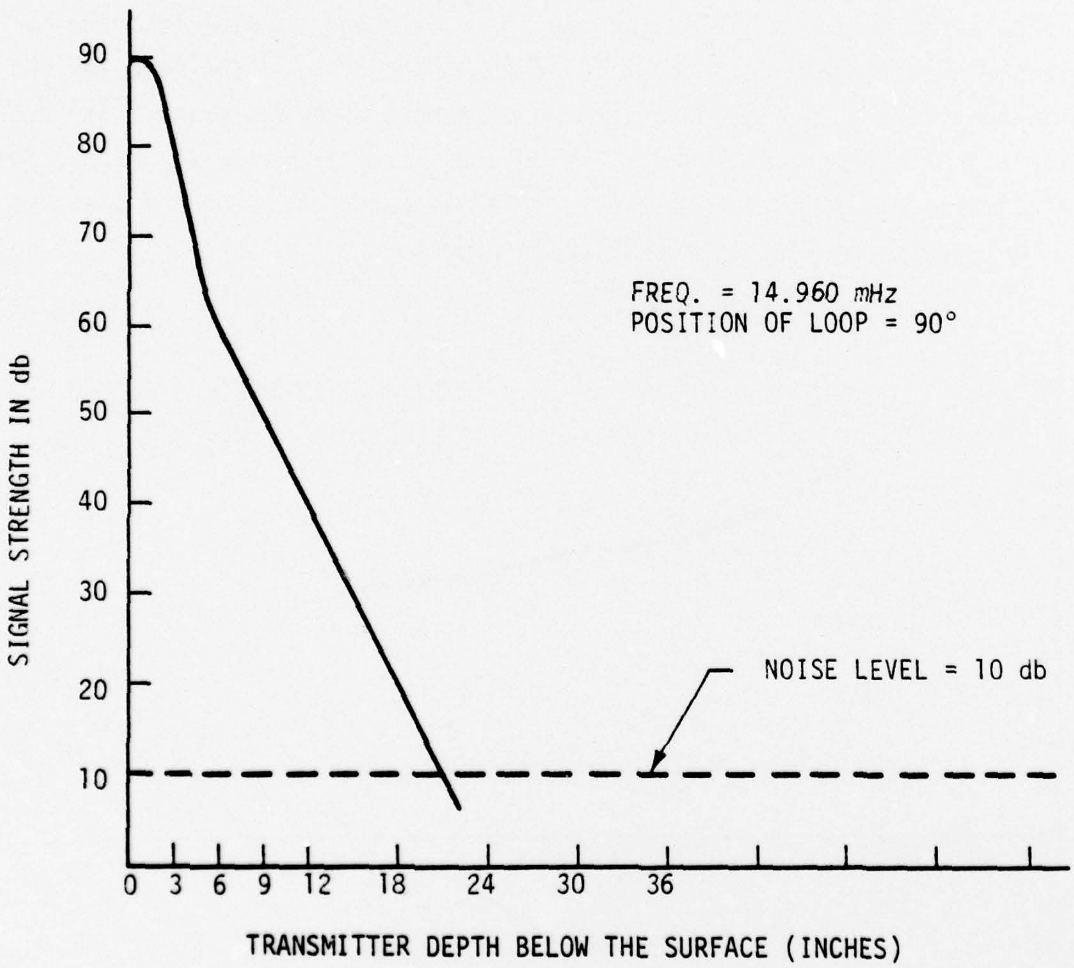
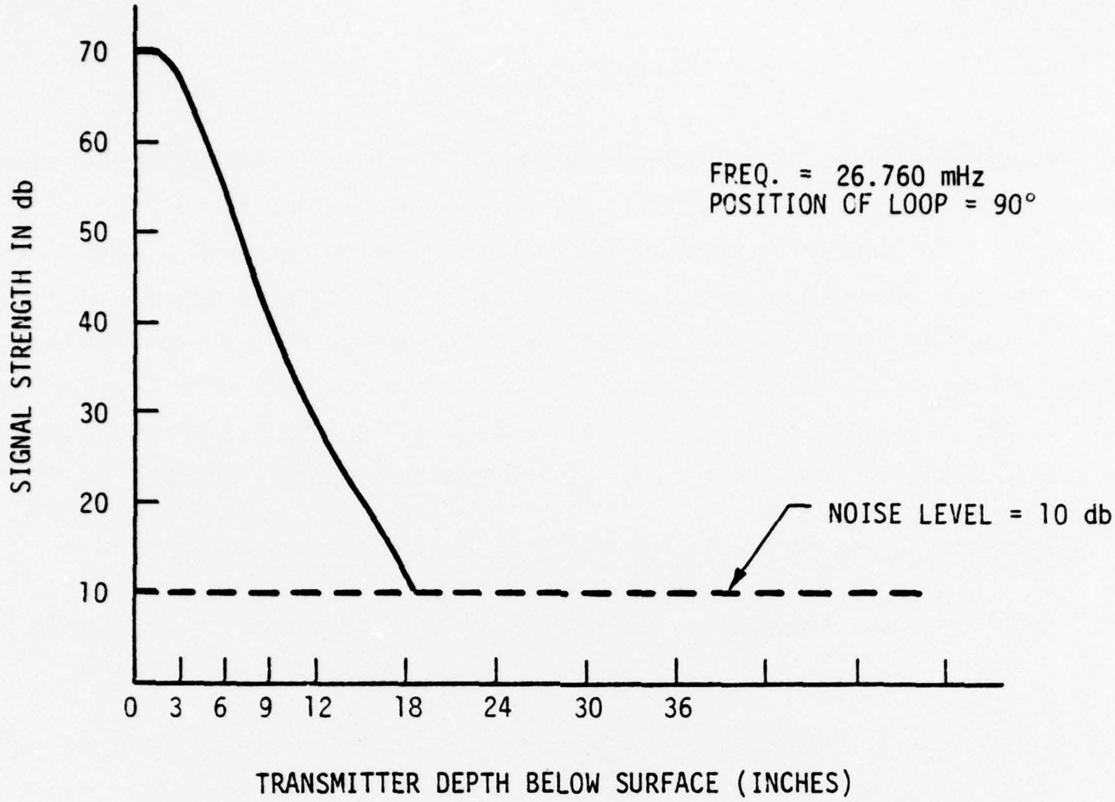


FIGURE 10. RESULTS OF TEST 2s: SIGNAL STRENGTH VS. DEPTH OF IMMERSION



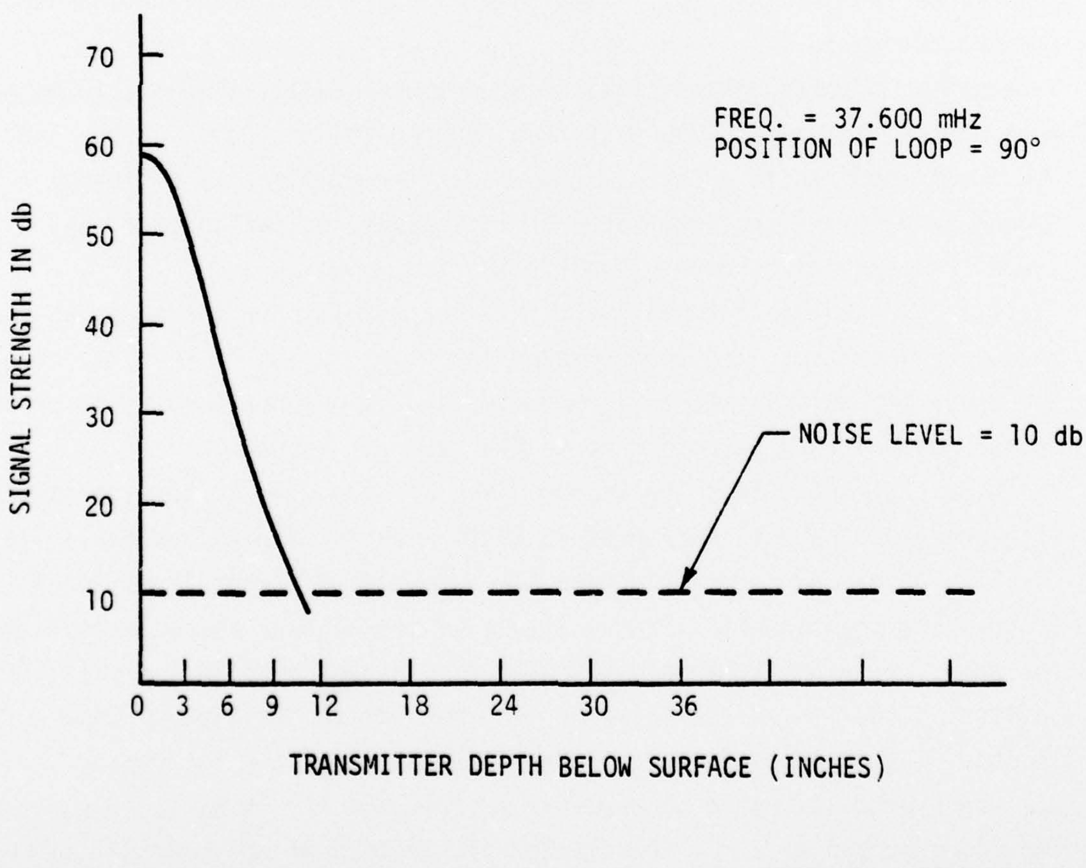


FIGURE 10. RESULTS OF TEST 2s: SIGNAL STRENGTH VS. DEPTH OF IMMERSION, Concluded

2.3 Bench (Life) Test

A bench life test was made to determine the amount of transmitter output vs. time. The unit tested (14.950 mHz transmitter) was powered by a standard Mallory M-1611 9 volt battery. The transmitter had a new battery installed and was placed at two locations from the receiver, 8 ft and 30 ft. Using a non-matched antenna (4 ft), the signal strength was recorded using the Johnson receiver at the two locations and plotted against time-from-actuation. The data from the test were recorded as "S units" which corresponded to a relative strength scale. Each S unit was equivalent to approximately 3 db. The results of the test are shown in Figure 11.

2.4 Implications of Results of Fresh Water and Salt Water Tests

The results of the tests indicate several findings of importance for developing a MOS.

- A very small, lightweight underwater RF transmitter can be designed which will be useful at depths of up to 3 or 4 ft and still provide a significant range for use in a MOS. This range was over a mile using the demonstrated hardware.
- Attenuation of transmitted signals depends upon water salinity, submergence depth, and signal frequency (see Figure 12a and 12d).
- The power required to penetrate the water/air interface is frequency dependent - lower frequency requires less power, or put another way, lower frequency gives more range for the same power.
- The size of the loop antenna built into the transmitter increases as the frequency decreases - an unfortunate fact.
- The range of the transmitter is affected by the orientation of the transmitter loop antenna in reference to the receiver antenna.
- The life test shows that the transmitter will continue to operate (although with decreased output) for about 48 hours with a standard battery. The use of a ni-cad battery would keep the output at a higher level for a longer time than shown in Figure 11 due to the battery characteristics.
- The pulse (time on vs. time off) could also be modified to increase life. Obviously, the longer the pulse is "on" the faster the battery drain.
- It should be noted that short system life can be easily tolerated, Since the man overboard should be recovered fairly quickly if he is to survive. The power output of a MOS transmitter (regardless of pulse ratio) may be increased considerably at the expense of time of a 48+ hour battery life.

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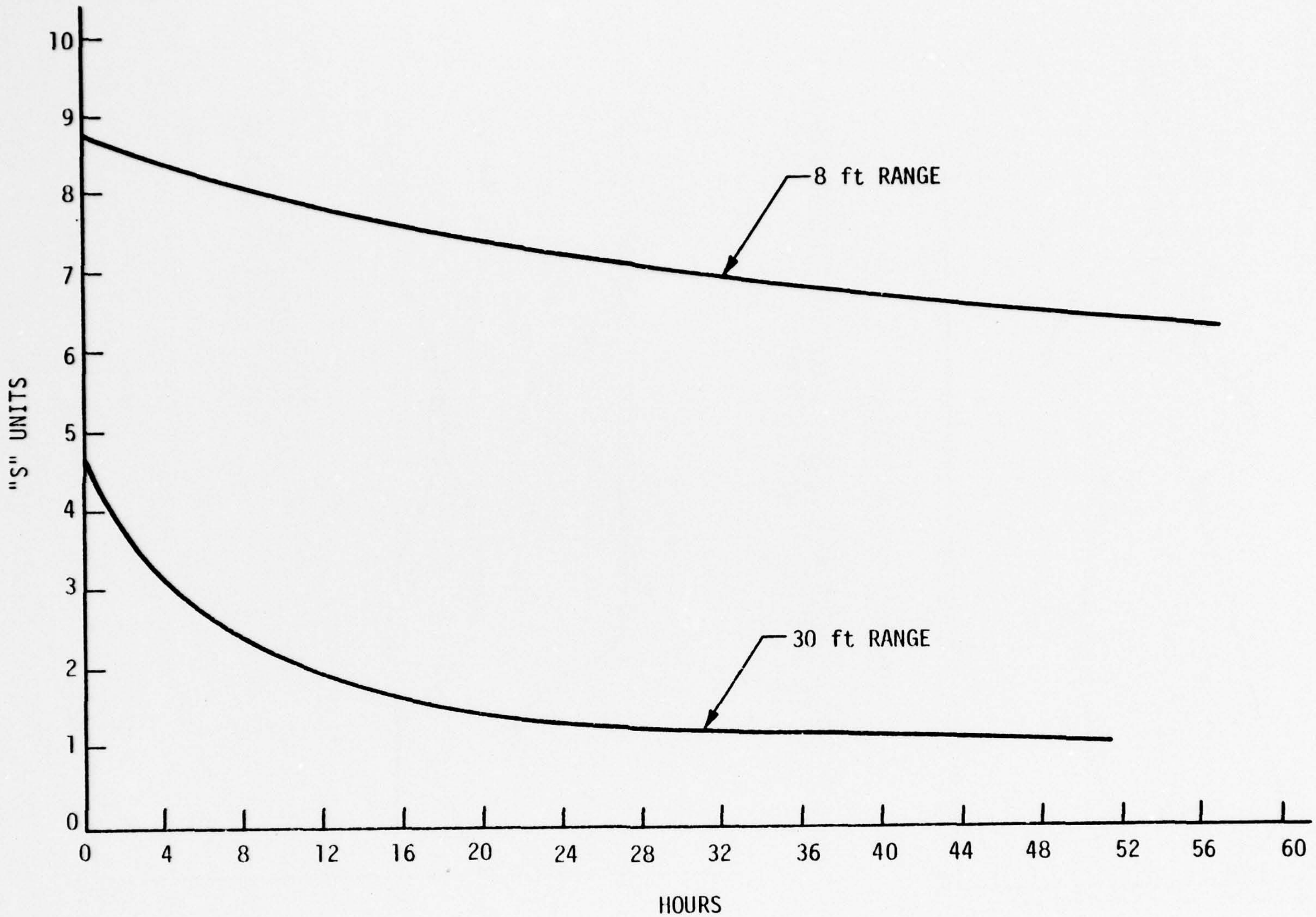

FIGURE 11. BENCH LIFE TEST TRANSMITTER OUTPUT VS. HOURS WITH NEW MALLORY M-1611 9V BATTERY

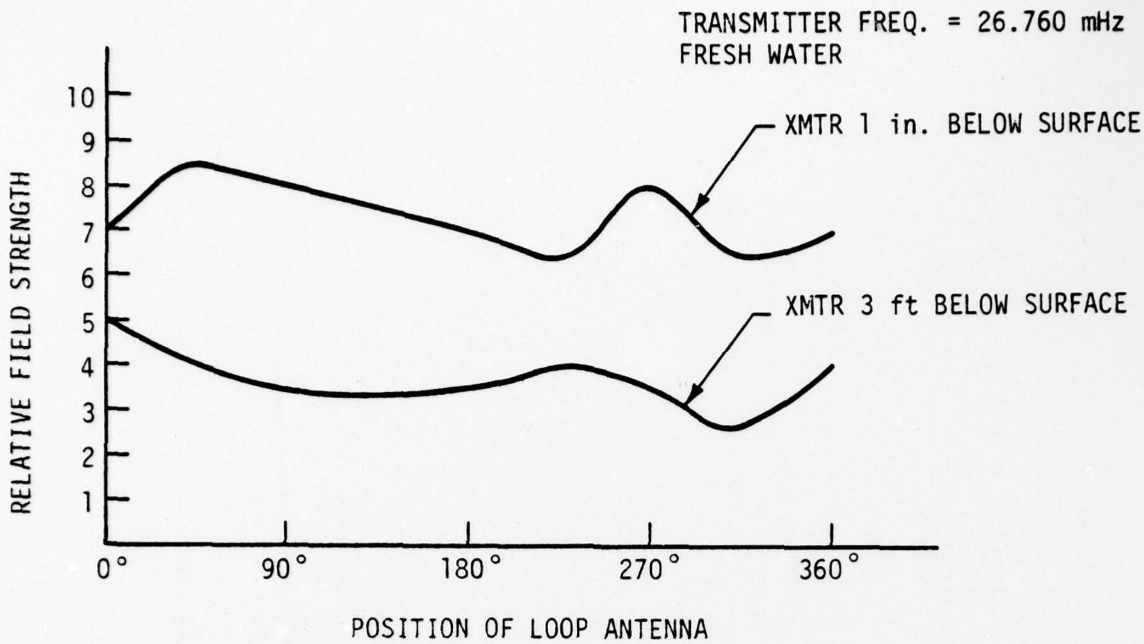

FIGURE 12a. SUMMARY OF FRESH WATER TESTS: RELATIVE FIELD STRENGTH VS. POSITION OF LOOP ANTENNA

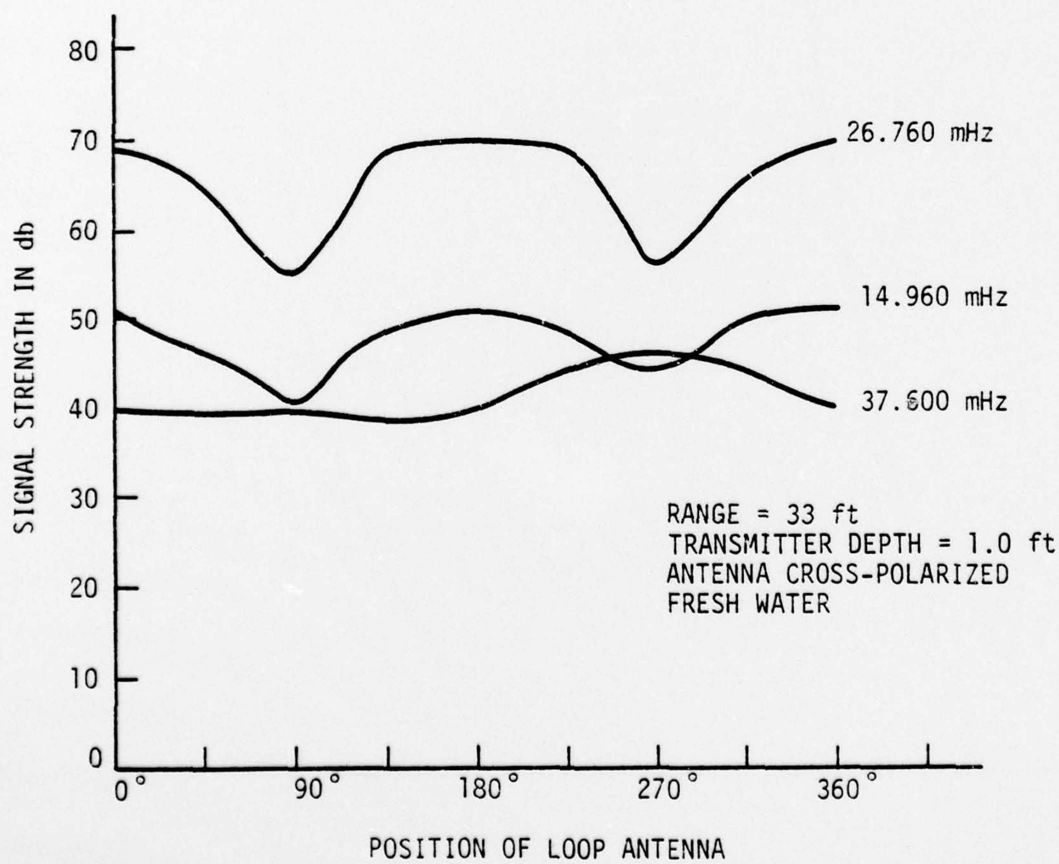

FIGURE 12b. SUMMARY OF FRESH WATER TESTS: SIGNAL STRENGTH VS. POSITION OF LOOP ANTENNA

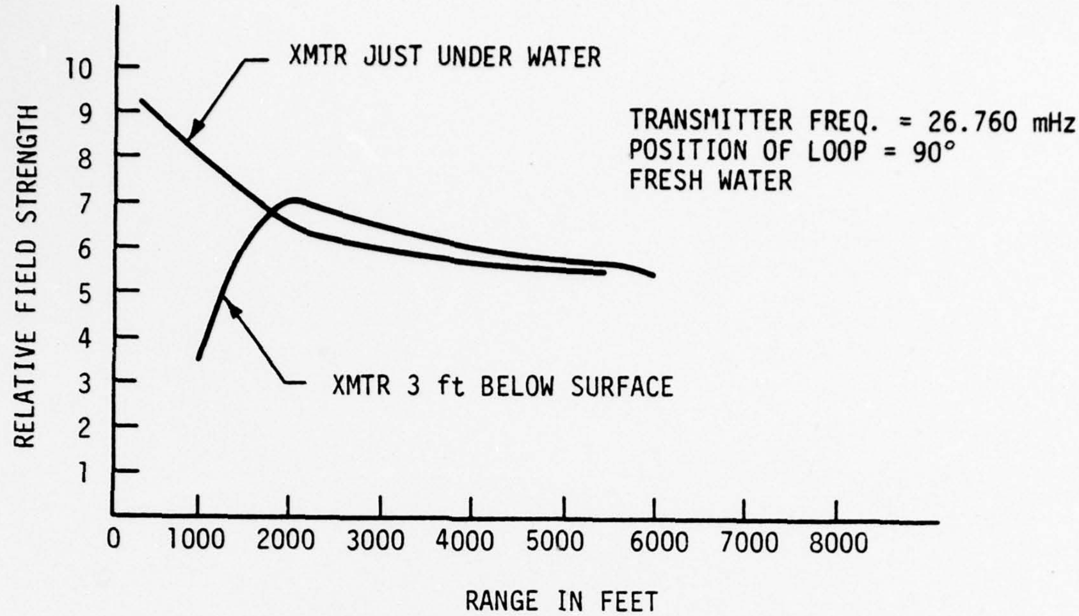

FIGURE 12c. SUMMARY OF FRESH WATER TESTS: RELATIVE FIELD STRENGTH VS. RANGE

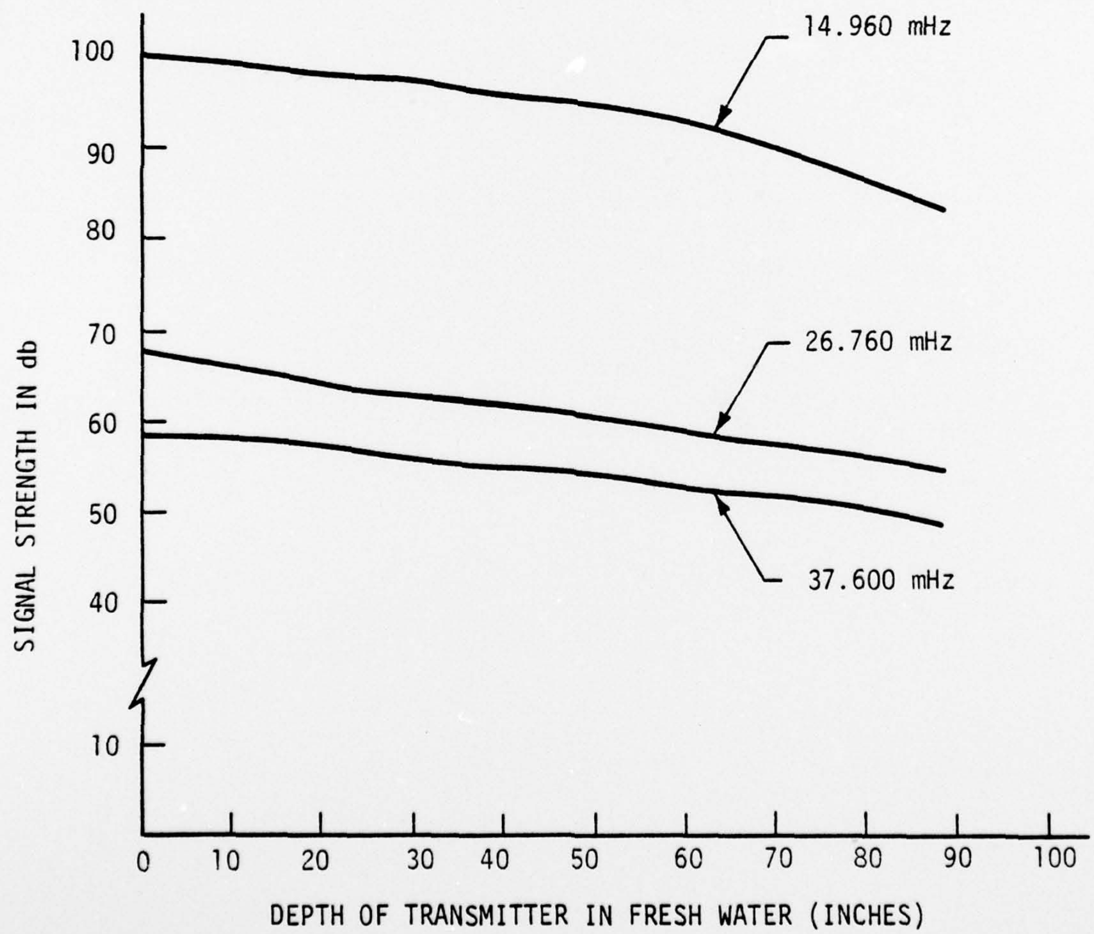

FIGURE 12d. SUMMARY OF FRESH WATER TESTS: SIGNAL STRENGTH VS. DEPTH OF TRANSMITTER

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APPENDIX B - SOME PRACTICAL CONSIDERATIONS FOR DESIGN AND USE OF THE MAN OVERBOARD SYSTEM CONCEPT

1.0 THE APPROACH

The concept discussed here is not intended to be a recommended approach, but is intended to demonstrate that the approach can, indeed, be workable on merchant vessels. This presentation provides means for a ship's crew to become immediately aware of a man overboard situation and to constantly monitor the victim's bearing (true and/or relative) for a successful recovery of a man overboard. In some cases, the practical considerations will vary somewhat from the equipment and procedures listed in the text of the report (e.g., the use of a supplemental portable receiver to be taken in the lifeboat on the recovery of the victim, and the digital readout of relative bearings of the RF signal on both portable and master receivers). The material was prepared by two former merchant seamen both of whom have had shipboard emergencies including the man overboard situation. The intent of the presentation is to illustrate from the experienced seaman's point of view how the proposed concept of the MOS can be used for detection and location of the man overboard victim. The principle author holds a First Mate's license and has attended two maritime schools in the United Kingdom; the secondary author holds USCG QMED and lifeboat certification and has experience on more than 16 vessels.

2.0 EQUIPMENT AND OPERATION

The equipment desirable for the search and rescue operation in the man overboard situation could include three pieces of receiving equipment:

- master receiver on bridge for continuous monitoring of MOS signals
- portable receiver for use in the lifeboats during recovery of the victim; monitoring of MOS signals only during rescue operations
- boat to ship communication radio.

2.1 Master Receiver

The master receiver is a limited frequency receiver unit (Figure 1). This receiver would be capable of receiving signals on any of the currently designated international maritime or aviation distress frequencies and/or the chosen additional MOS distress frequency. It should have some sensitivity to direction such as an ADF. The unit is mounted near the radar and in the vicinity of (though not too near) the standard compass for most convenient use. Upon transmission of the MOS frequency (i.e., activation of a MOS transmitter), the vessel's master receiver would automatically activate the vessel's crew alarm system.

A selector switch would enable selection of any of the above frequencies. There could be a small response indicator light to acknowledge receipt of a signal <u>no matter how faint</u>. This receiving mode should be coupled with the signal strength meter and an audio alarm so that <u>NO</u> signal goes undetected.

An alarm cancel button would be located under a springloaded cap so that the overall system could receive a distress signal from another vessel but not disturb the entire ship's company by activating the general alarms. Presumably these alarms would be located on the bridge, on deck, and in the engine room.

The master receiver unit would, if coupled to the gyro and radar, give a converted true bearing of the signal source. However, if the unit was not coupled to the gyro, then the relative bearings could be registered on an appropriate port or starboard bearing indicator on the master receiver. It should be noted that the display of relative bearing could vary from a digital readout (Figures 1 and 2) to a less complex needle-dial display (not shown). Remote actuation switches for release of life supporting devices are also pictured on the master receiver in Figure 1.

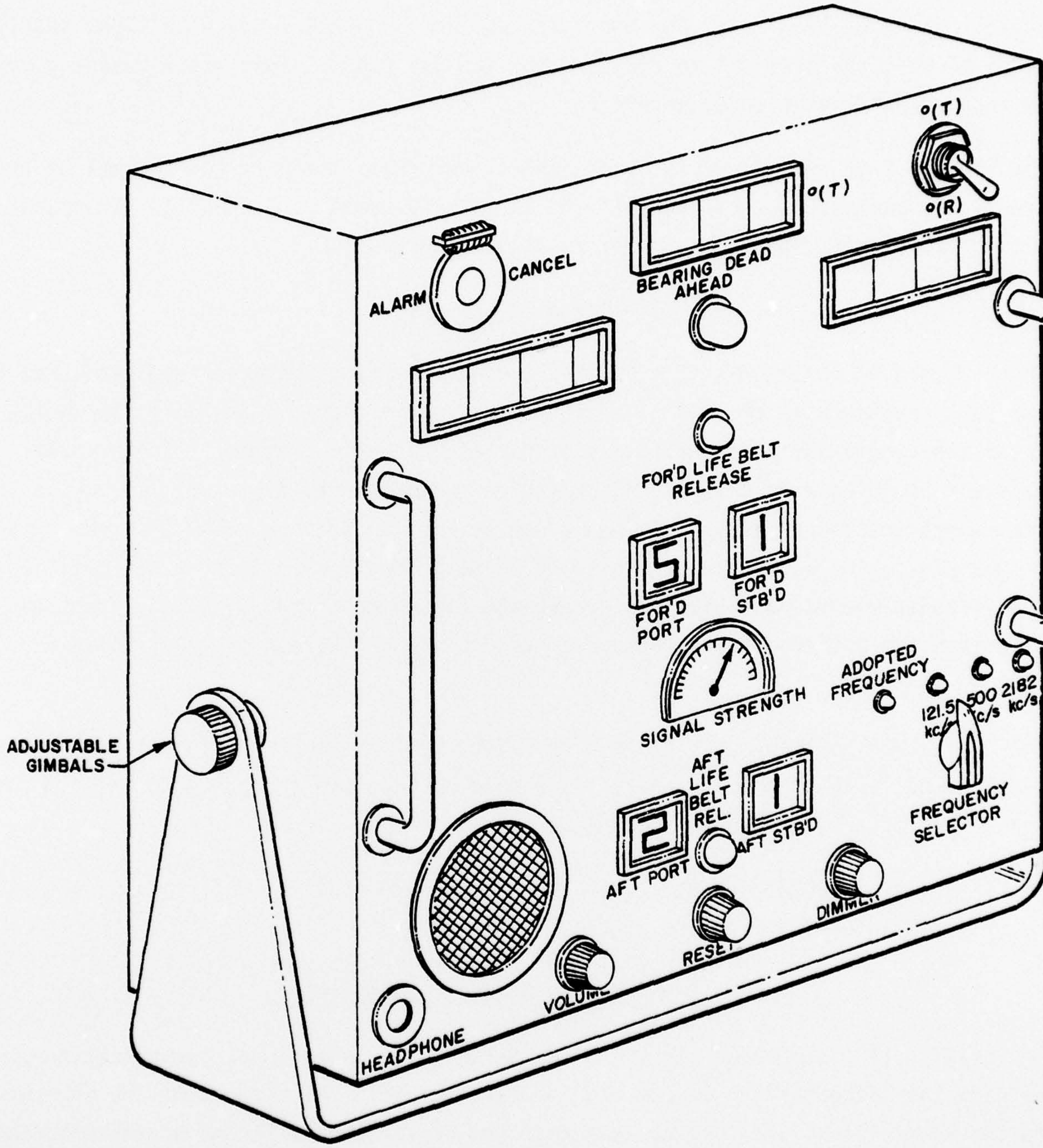

FIGURE 1. IDEALIZED MASTER RECEIVER TO BE LOCATED ON SHIP'S BRIDGE

The master receiver unit could have a diagramatic plan of the vessel and relevantly placed light emitting diode readouts which would give an indication as to the first location of the origin of the man overboard such as fore and aft and port or starboard. When the bearing of the man overboard is dead-ahead, the blue light should flash to warn the crew not to run down the man overboard. This visual warning may be supplemented by an audio warning.

The various switches, controls, and dimmers would have standard configurations and symbols to maximize the capacity of the operator's rapid comprehension for operation of this unit under pressure of an actual emergency.

2.2 Portable Receiver

The portable receiver unit (Figure 2) would be a battery operated receiver tuned to the same frequency as the MOS transmitter. It would serve as the unit for homing in on the victim during the recovery operation using the lifeboat. The portable receiver would be kept charged and stowed on the bridge ready for dispatch with the boat party (recovery party). It would not be used to monitor the MOS signal until it was placed in the lifeboat. It would be most inadvisable to stow the unit in the lifeboat due to possible loss during the launching of the lifeboat, probable deterioration during adverse weather conditions, and the risk of theft while in port.

The unit would be previously aligned or calibrated for locking into place along the longitudinal axis of the lifeboat. It should be in close proximity to the compass for an uncluttered viewing by the helmsman.

The lifeboat portable unit would, of course, be waterproof, light, robust, and have quickly rechargeable batteries.

2.3 Boat to Ship Communication Radio

The boat to ship communication radio is the unit for maintaining communication between the lifboat after launch and the parent ship. The purpose of the communication unit is two fold: 1) to keep the crew of the ship informed of the progress in reaching the victim, and 2) to offer additional location information gathered from the master receiver and the ship's lookouts. This unit would be required in the event that the portable receiver was not used since all bearing information would be provided only at the bridge of the vessel. A simplified illustration of MOS components for the lifeboat is shown in Figure 3.

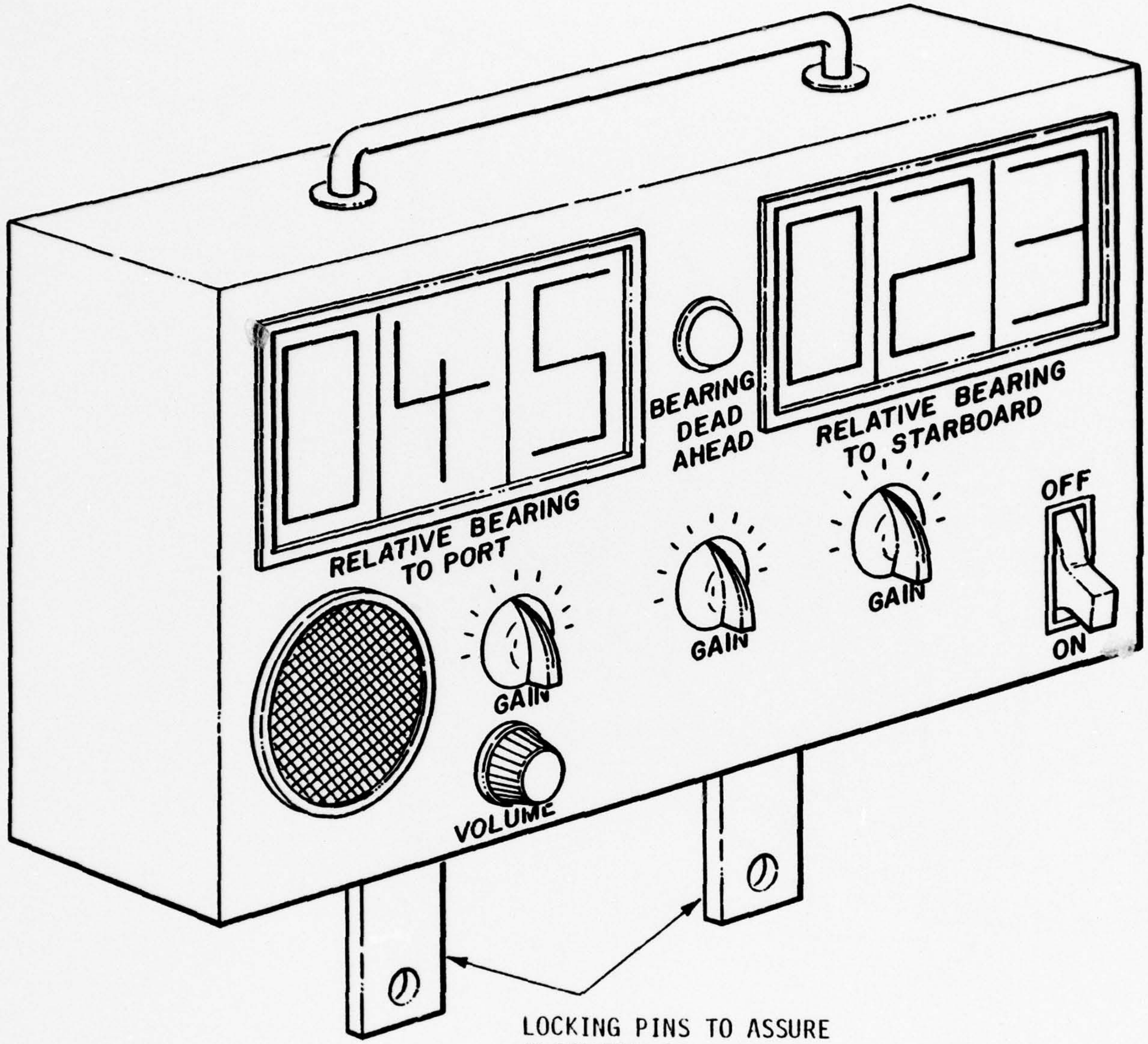

FIGURE 2. IDEALIZED PORTABLE RECEIVER FOR LIFEBOAT USE

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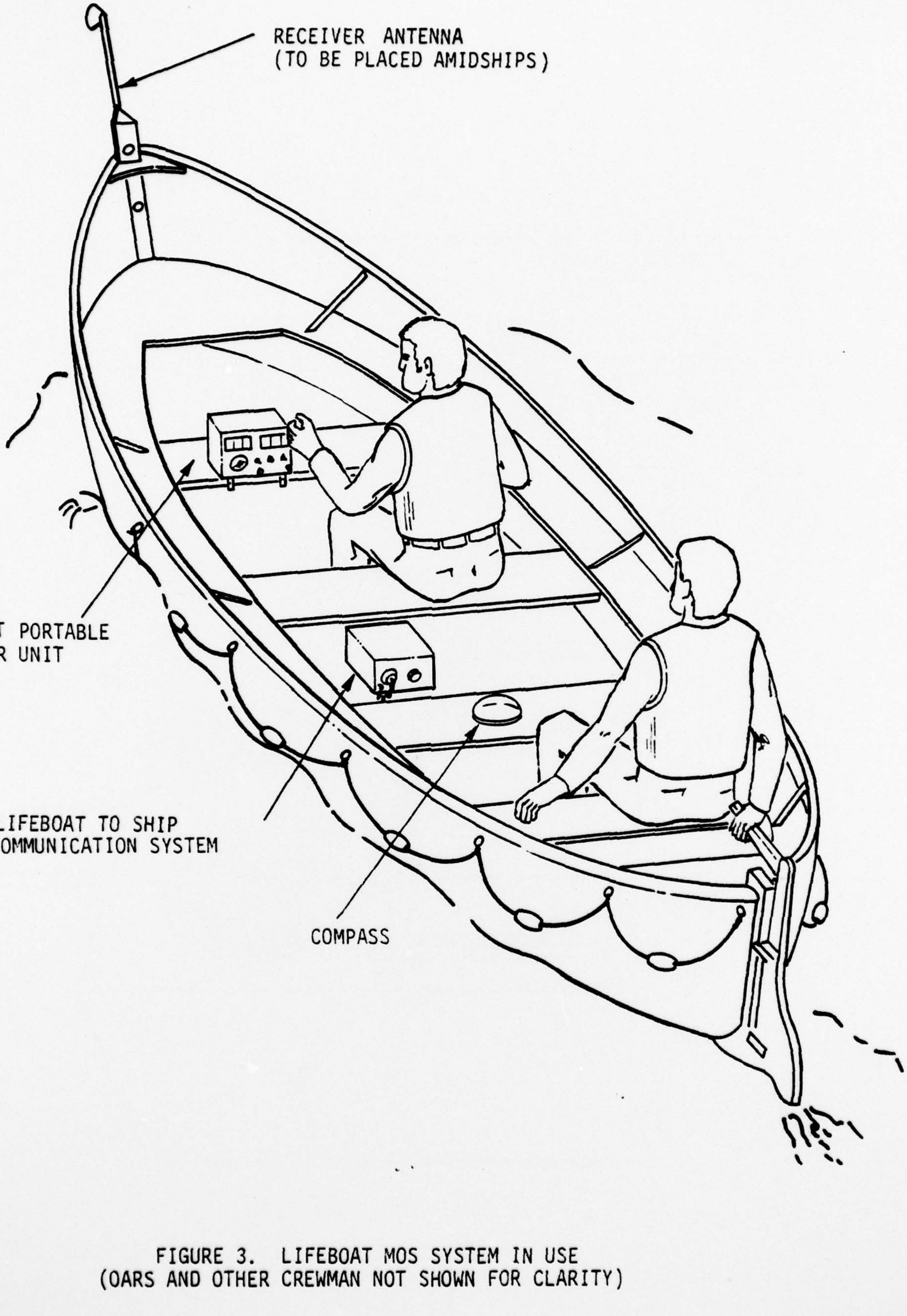

FIGURE 3. LIFEBOAT MOS SYSTEM IN USE
(OARS AND OTHER CREWMAN NOT SHOWN FOR CLARITY)

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3.0 PROCEDURE FOR USE

The following step by step procedure would be an acceptable method for recovery of a man overboard in open sea with a relatively calm sea state.

The weather, traffic, density, amount of sea-room and the handing characteristics of the vessel are all major factors of the varying approaches that could be used to expedite the successful recovery of the man overboard. The following steps incorporate presently recommended procedures for use in the man overboard situation on open sea passages.

- Man falls overboard
- Distress signal received by master receiver on bridge
- Man Overboard System (MOS) actuated and alarm sounds on bridge and in engine room (optional deck alarm)
- Crew on bridge sound general quarters and boat station alarms
- Crew on bridge release appropriate ring buoy (with lighted smoke float attached and possible ELT/EPRIB) using remote actuation
- Wheel hard over to side man is reported overboard to sweep the propeller clear of him
- Signal "stop all engines"; engine room crew answers and complies
- Commence relevant whistle signals and visual light and flag signals
- Post lookouts if not already on bridge and other positions with high visibility for maintaining visual contact of man overboard
- Resume forward speed and commence Williamson Turn (sea-room permitting) to return to vicinity of man overboard
- Boat parties report to stations and commence clearing boats; commence installing the portable MOS receiver and boat to ship communication unit
- First aid party mustered for commencing preparations to receive man overboard
- Commence activating direction finder set if not already "ON"
- Commence radar surveillance if already "ON" thus giving tracking of lifeboat and, of course, indication of other traffic in area
- Observe true or relative bearing of victim very carefully and constantly using MOS receiver

- Bring vessel round out of Williamson turn to form a lee for the lifeboat to be lowered in
- Take care not to run victim down. This is prevented by blue light and audio alarm warnings when MOS transmitter unit is reported dead ahead
- Send lifeboat away
- Constantly check relative bearing from lifeboat to victim advising the lifeboat by radio communication to confirm their receiver bearings
- Compare relative bearing from lifeboat to parent vessel's true bearing (and range if available from radar)
- Plot on chart and/or radar screen relative bearings from both parent vessel and lifeboat
- Calculate relative bearing and range of man overboard from lifeboat and direct lifeboat to victim by lifeboat's compass course (and distance if possible)
- Rescue victim
- Lifeboat returns to parent vessel and first aid is administered
- Reset MOS to original state of readiness and de-activate transmitter
- Secure for continuation of sea passage.

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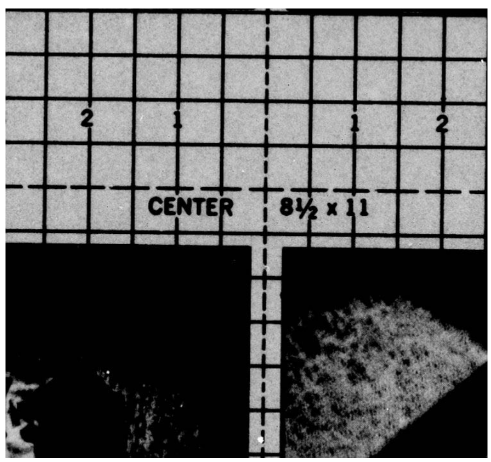
all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1
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